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PRELIMINARY INVESTIGATION OF THE MIXING
OF A PULSATING AIR JET
IN A STEADY SECONDARY AIRFLOW

A Thesis

Submitted to the Graduate Faculty

of the University of Minnesota

by

Charles J. Burton

Lt. Comdr., U.S. Navy

In Partial Fulfillment of the Requirements
for the Degree of
Master of Science in Aeronautical Engineering

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for the degree of
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These studies, reports, and documents are submitted to the author at the University of Minnesota as a contribution to the literature of the subject.

Free of charge to the author.

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SUMMARY

An investigation of the mixing region of a cool isothermal pulsating air jet in a steady secondary airstream at Reynolds number = 41,000, velocity ratio ≈ 0.5 , primary velocity ≈ 200 fps, was conducted by means of a velocity survey of the region, utilizing a total head tube, static pressure orifice, and a sampling valve, which by rotation and synchronization with the pulse producing valve, applied a constant but different pressure differential to each one of 36 manometer tubes in succession, producing a standing wave of dynamic pressure of the pulse cycle.

The pulsating flow mixing region was compared to the mixing region of a steady flow jet of similar configuration and found to differ very slightly, if at all. The mixing region agreed closely with that defined by previous steady flow investigations.

The investigation was conducted under the auspices of the Mechanical and Aeronautical Engineering Departments of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science.

CONCLUSION

An investigation of the mixing region of a cool jet
discharge into a hot gas in a steady boundary layer at
Mach number = 4.5, velocity ratio 1.5, and velocity in
jet, was conducted by means of a velocity survey of the
region, resulting a total mass flow, static pressure, and
a velocity ratio, which by rotation and acceleration of
the pulse producing valve, applied a constant but different
pressure differential to each one of the two jets in the
nozzle, producing a standing wave of dynamic pressure of the
pulse type.

The mixing flow region was compared to the
mixing region of a steady flow jet of similar conditions and
found to differ very slightly, it was also. The mixing region
agreed closely with that defined by previous steady flow investi-
gations.

The investigation was conducted under the auspices of
the Mechanical and Metallurgical Engineering Department of the
University of Minnesota in partial fulfillment of the require-
ments for the degree of Master of Science.

INTRODUCTION

The Statement of the Problem

The mixing of fluid jet with surrounding fluid has been investigated analytically with experimental confirmation by numerous investigators for various configurations of flow, but has always been limited to the steady flow cases. Based on Prandtl's mixing length concept for turbulent flow (1) [as modified by Taylor (2)], Tollmien (3) and Kuethe (4) have produced and confirmed theoretical analyses, of the extent and nature of the turbulent mixing regions formed by free jets.

Two excellent summaries of isothermal and non isothermal air jet investigations are reports by Cleaves and Boelter (5), and by Shapiro and Forstall (6), the latter report offering useful empirical relations for the shape of the mixing region.

Unfortunately, the non-steady flow case in which there exist pulsations of a random nature, and even that case in which the pulsations are regular, have not lent themselves to analytical treatment. It is felt that statistical methods will soon be brought to bear on the subject with productive results, but it is also desirable that supplementary data be introduced by experimental investigations.

INTRODUCTION

The Statement of the Problem

The main aim of this report is to provide a summary of the results of the investigation into the effect of the concentration of the solution on the rate of the reaction. The investigation was carried out by means of the method of initial rates. The results of the investigation are given in the form of a table and a graph. The results show that the rate of the reaction increases with the concentration of the solution. The results are also in agreement with the theoretical predictions.

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The design engineer of turbojet, ramjet or pulsejet engine combustion chambers is confronted with a need for design data concerning the mixing of fuel vapor and air under highly turbulent conditions, often times under conditions of regular pulsing flow as in the case of the pulse-jet engine, or when resonant conditions exist in the combustion chambers of other types of jet engines.

It has been found by Godsey and Young (7) that such conditions exist in a gas turbine combustion chamber as evidenced by observed flickering of the flame front position at frequencies in 6000 cps, 250 to 600 cps, and 25-60 cps regions. And Scurlock (8) concludes that rough burning is due to random fluctuations in the mass flow, caused by fluctuations in the pressure drop which are in turn caused by random fluctuations of the fraction burned in any cross-section; and that resonance or flutter occurs when the period of vibration is the resonant frequency of some part of the system.

It is felt that a study of the basic mixing problem is a necessary prelude to further studies involving actual combustion. It is the purpose of this investigation, then, to show the extent of the mixing region of a low frequency pulsating air jet in a steady secondary air flow by means of a velocity survey of the region.

Basis of Solution of the Problem

The approach to this phase of the problem is experimental in nature. The axial velocity field can be charted by making a survey of the mixing region with a total head tube and static pressure taps. The difficulties involved in measuring non-steady pressures can be overcome, if the pressure variation is periodic, by use of a sampling valve which presents an open passage to a particular manometer at one point in the pressure cycle only and at the same point each cycle. Assuming no leakage from the tube during the rest of the cycle, the particular tube then is subjected to a steady pressure rather than a varying one. Use of many tubes, each recording a different point in the cycle then produces a standing wave of the pressure pulsation.

Static pressure readings can be taken at the edge of the flow for all points within the flow at a particular cross-section. Prandtl (1) has shown and Tollmien (3) has confirmed that the static pressure is constant across the jet within very small limits.

Direct comparison of the mixing region of a pulsating jet and the mixing region of a steady jet of similar strength will provide a measure of the pulsation mixing region as well as

Basics of Population of the Region

The approach to this phase of the problem is complex -
related in nature. The initial velocity field can be derived by
making a survey of the initial region with a total field and
static pressure term. The differential analysis is performed
under steady conditions and is concerned, at the present writing,
is periodic, by use of a sampling rate which permits an open
passage to a particular parameter at one point in the process
cycle only and at the same point each cycle. Assumed in this
case from the time being the rest of the cycle, the particular
rule time is neglected - steady pressure terms can be very
large and, due to very subtle, such recording a different point
in the cycle than produces a sampling error of the pressure field.
then.

Static pressure readings can be taken at the edge of
the flow for all points along the flow at a particular cross-
section. Figure 11) can show and illustrate (2) two conditions
that the static pressure is constant across the flow field very
small distance.

Direct comparison of the static region of a pulsating
flow and the static region of a steady flow of similar strength
will provide a measure of the pulsation static pressure as well as

its relationship to the world, the idea of the world

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THE APPARATUS

General Description of Complete Apparatus

A schematic diagram of the apparatus used is shown in Fig. 1. Photographs of the apparatus components are Fig. 3 to Fig. 10.

The apparatus consisted of an air supply system capable of furnishing air to two flow lines which divided the air supply for primary and secondary air flow and which contained standard A.S.M.E. square edge orifices with "radius" taps as described in Ref. (9) for measurement of the mass rate of flow in each flow line. The primary flow passed through 2" standard galvanized pipe to a rotating disc type butterfly valve, which served as the source of pulsations, from whence it was smoothly ^{reduced} ~~reached~~ down to a one inch inside diameter brass tube and ejected into the test section as a free jet. The butterfly valve was separated from the measuring orifice by a $2\frac{1}{2}$ ft. by 7 ft. cylindrical surge tank to prevent the pressure pulsations from traveling upstream to the orifice and affecting its accuracy.

The secondary flow passed through a six inch I.D. smooth black-iron pipe, which contained the measuring orifice, to a 22 inch by 35 inch steel drum which served as a plenum cham-

APPENDIX

General description of the apparatus

A schematic diagram of the apparatus used is shown in Fig. 1. The principle of the apparatus is as follows: A gas sample is introduced into the apparatus from a gas cylinder. The gas sample is then passed through a series of traps and filters, and is then collected in a gas sample bag. The gas sample bag is then analyzed for the presence of the gas of interest.

The apparatus consists of a gas sample cylinder, a series of traps and filters, and a gas sample bag. The gas sample cylinder is connected to the traps and filters by a series of tubes. The traps and filters are connected to the gas sample bag by a series of tubes. The gas sample cylinder is filled with a gas sample. The gas sample is then passed through the traps and filters, and is then collected in the gas sample bag. The gas sample bag is then analyzed for the presence of the gas of interest. The traps and filters are used to remove any impurities from the gas sample. The gas sample bag is used to collect the gas sample. The gas sample bag is then analyzed for the presence of the gas of interest. The traps and filters are used to remove any impurities from the gas sample. The gas sample bag is used to collect the gas sample. The gas sample bag is then analyzed for the presence of the gas of interest.

The apparatus was used to collect gas samples from a gas cylinder. The gas sample was then analyzed for the presence of the gas of interest. The traps and filters were used to remove any impurities from the gas sample. The gas sample bag was used to collect the gas sample. The gas sample bag was then analyzed for the presence of the gas of interest.

ber and which surrounded the primary flow exit line concentrically. The secondary flow was then exited from the drum into a square "bell" which had an entrance dimension of 11 x 11 inches and which tapered smoothly to the 6 3/16 inch square test section to permit smooth entrance of the secondary flow into the test section, surrounding and concentric to the primary air jet. Eighteen-mesh screen was placed 14 inches upstream in the flow to assist in getting isotropic small scale turbulence at the test section entrance.

The test section consisted of an 8 ft. long square duct constructed of angle iron reinforced, smooth $\frac{1}{8}$ in. plywood. One side of the duct was constructed to slide so that the total head tube and static orifice located in the sliding panel could be placed at any desired station, longitudinally, in the test section. The downstream end of the duct was open.

The total head tube and static orifice pressure leads were connected to a rotating sampling valve which was synchronized with the rotating butterfly valve so that a standing wave of total pressure minus static pressure could be produced on a bank of U-tube manometers.

ber and which surrounded the entire floor area of the
ly. The secondary flow was then raised from the floor into a square
"bell" which had an internal diameter of 11 x 11 inches and
which tapered slightly to the 8 1/2 inch square top section in
which the flow of the secondary flow into the top was
tion, surrounding and connecting to the primary air jet. This
section was placed in the center of the floor in the
near in getting into the small hole in the floor at the top
section entrance.

The first section consisted of an 8 ft. long square
duct surrounded at right angles from the entrance, section 1 in. diameter.
One side of the duct was connected to the air in the main
head tube and the other side of the duct was connected to the
be placed at an elevated station, horizontally, in the duct
section. The diameter of the duct was 8 in.

The total flow rate was then divided into two parts. One
was connected to a rotating assembly with a motor and a pressure
with the rotating assembly valve so that a steady flow of
total pressure was maintained. The pressure could be produced in a tank
of 100 psi pressure.

The Pressure Sampling Valve

It was desired to know the variation of velocity, and thus pressure, with time in the mixing region. Available for this purpose was a rotating pressure sampling valve, constructed by E. R. Becker for his Master's Thesis (10). A schematic diagram of the sampling valve is shown in Fig. 2 and photographs of the valve and its associated drive mechanism and manometer board in Fig. 2-b to Fig. 2-h.

As described in Ref. 10 and Ref. 11, the valve consists of a truncated cone shaped rotor (A) which rotates within an outer casing (B). Two circumferential grooves, (C) and (D), have been machined in the conical section. Drilled in the outer casing, so that they match up with the two grooves in the conical section, are two pressure taps, (E) and (F). The pressure leads from the total head tube and the static pressure orifice at the test section were attached to these taps. An L shaped passage (G) has been made in each of the outer lands of the conical section resulting in a single hole in the face of the land. Drilled in the outer casing are 72 holes, 36 equally spaced in each of the two rings. These are situated to line up with the holes in the lands of the inner rotor. The outer casing is restricted from rotating by the pin (H) which passes through a slot in the supporting base (I). The rotor is driven by a pulley and the outer

casing is held up on the taper by a spring arrangement. The outer casing is six inches in diameter at its largest and is tapered to a 30° included angle. It is supported by a pair of bearings and pillow blocks which provide for easy disassembly of the valve.

The principle of operation of the valve is as follows. The pressure changes are transmitted through the connections into the two circumferential grooves machined in the surface of the rotor and up through the L shaped passages drilled in the two outer lands. As the conical rotor rotates, the pair of holes in the lands pass each of the 36 pairs of holes in the outer casing in succession. Different pressures exist in the L shaped passages as each pair is passed, but if the rotor is in synchronization with the pulsation frequency, and the pulsation is regular, the same pressures will exist in the L shaped passages each time the holes in the rotor lands pass a particular pair of holes in the outer casing. Thus, if connections are made to a different U-tube manometer from each pair of holes in the outer casing which occupy the same circumferential position, the pressure difference as it occurs at the particular point in the cycle of pulsation will be registered. With each of the 36 pairs of holes connected to U-tube manometers arranged in a bank, a standing wave showing the Δp at each 10° increment of the pulse cycle will appear on the manometer bank. This assumes that (1) the

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level of the fluid in manometers have a common reference level, (2) that no leakage occurs from a tube, between successive applications of the Δp to that tube, and (3) that no additional positive or negative pressure is produced by the dynamic effects of the valve rotation itself. As will be described later, item (2) is a source of error which can be reduced by rotating the valve at speeds greater than 200 rpm and item (3) is a source of marked error which only calibration can lessen in the valve's present configuration.

The valve was driven by a $\frac{1}{2}$ hp, 110 volt, 1750 rpm, AC electric motor through a system of two 6 inch variable speed pulleys. An 8 inch pulley on the shaft of the inner rotor of the valve combined with these two variable speed pulleys afforded a speed range of 120 to 370 rpm.

The Pulsator

The source of pulsations in the primary flow was provided by a 2 inch diameter disc type butterfly valve which rotated in the primary flow pipe. The valve completely closed the passage when closed, thus the air flow varied from zero to maximum. The butterfly valve was connected to the inner rotor shaft of the sampler by a flexible shaft and a 2:1 gear ratio. The reduction gear synchronized the sampler valve and butterfly valve since one revolution of the butterfly valve constituted two complete pressure variation cycles.

The frequency of pulsation was adjusted by the variable speed pulley system and was controlled during runs by use of a stroboscope to accurately attain and maintain the desired pulse frequency.

The Airflow System

The air supply used for the tests was obtained from a permanent installation located in the turbine test cell of the Mechanical Engineering Department. A gasoline powered Lycoming Model O-435-T air cooled Army tank engine, rated at 162 hp at 2800 rpm, drives a centrifugal compressor. The compressor is a 7.48:1 gear ratio supercharger taken from an Allison V-1710 aircraft engine. The speed of the blower can be accurately controlled by throttling the engine.

A standard A.S.M.E. square edged orifice is mounted upstream of the blower inlet to permit evaluation of the mass rate of flow through the blower and to permit accurate maintenance of a desired flow rate.

The pressure differences, by means of total pressure and static pressure, are indicated on the Pitot-static probe and velocity head probe.

The pressure drops across the square edged orifice, settling chamber, and diffuser were measured with well type manometers. The pressure taps from the orifice were located in accordance with A.S.M.E. standards for "static taps". Also, the upstream tap being located 1 diameter from the upstream face of the orifice and the downstream tap 2 diameters from the downstream

The Airflow System

The air supply used for the tests was obtained from a
government installation located in the southern part of the
National Research Council, Department of Agriculture, located
about 10 miles from the test facility, where it is used
for the purpose of testing various types of aircraft. The
supply is obtained from a central station where the air is
filtered and then passed through a series of filters to
remove any dust or other particles. The speed of the airflow
is controlled by a valve which is operated by a hand
control.

A standard A.C. motor is used to operate the
valve. The motor is connected to the power line and is
operated by a switch which is located near the motor.
The speed of the airflow can be varied by adjusting the
valve.

Instrumentation

The total pressure was measured by a 0.028 inch O.D. total head tube of the Kiel type, which has a venturi shield surrounding the tube tip to insure flow normal to the 0.017 inch I.D. tube opening. The pitot tube shaft was $\frac{1}{8}$ inches O.D. brass which was mounted in a $\frac{1}{2}$ inch thick plexiglass plate through a leakproof packing gland so that the probe could be moved laterally across the test section width. The plexiglass plate also contained a $1/8$ inch diameter static orifice. The plate was mounted in the sliding wooden panel of the test section so that it could move up and down independent of and/or longitudinally, with the panel; thus, the probe could be positioned at any point in the whole test section duct as desired.

The pressure difference, Δp , between total pressure and static pressure was indicated on the U-tube manometer bank previously described.

The pressure drops across the square edged measuring orifices were measured with well type water-filled manometers. The pressure taps from the orifices were located in accordance with A.S.M.E. standards for "radius taps", Ref. (9), the upstream tap being located 1 diameter from the upstream face of the orifice and the downstream tap $\frac{1}{2}$ diameter from the downstream

face of the orifice. The static pressure holes were $\frac{1}{4}$ inch diameter and free of burrs and restrictions with slightly rounded edges.

The static pressure level at the upstream tap was measured on the same manometer used to measure the pressure drop by clamping the lead from the downstream tap and removing its other end from the manometer, causing the manometer to indicate gage pressure just upstream of the orifice.

The temperatures at the orifices were measured by iron-constantan thermocouples inserted in the flow upstream of the orifices in accordance with A.S.M.E. Standards. Temperature readings were made on a Brown direct indicating potentiometer.

The orifices were made to A.S.M.E. Standards and were machined to an inside diameter of 1.008 inches and 4.002 inches for the 2 inch primary line and the 6 inch secondary lines respectively.

A check on the accuracy of the orifices was made possible by the insertion of a measuring orifice at the blower inlet, which permitted a measurement of the total mass flow to compare with the sum of the flows through the primary and secondary lines as indicated by the other two measuring orifices.

from the office. The whole process takes about 1 hour and
about 100 ml. water and solution with slightly excess
sugar.

The whole process takes 10 to 15 minutes and the
result is a clear solution which is ready for use. The
solution is clear and the process is very simple. It
can be used for many purposes, such as for the
preparation of the solution.

The preparation of the solution was carried out in
a clean glass bottle. The solution is clear and
the process is very simple. It can be used for
many purposes, such as for the preparation of the
solution.

The solution was made in a clean glass bottle and
was found to be clear and ready for use. It was
found to be clear and ready for use. It was
found to be clear and ready for use. It was
found to be clear and ready for use.

A check on the quantity of the solution was made
by the use of a measuring cylinder. The solution
was found to be clear and ready for use. It was
found to be clear and ready for use. It was
found to be clear and ready for use. It was
found to be clear and ready for use.

Miscellaneous Apparatus

Flow Pipes. The A.S.M.E. code on fluid measurement does not recognize the use of any pipe smaller than 2 inch I.D. Consequently, 2 inch Standard galvanized iron pipe was used for the primary flow line and 6 inch I.D. smooth rolled black iron tubing for the secondary flow.

Surge Tanks. In order to prevent pulsations from the primary flow from affecting the measuring orifice in that line, the orifice was placed in series between two 7 ft. by 2½ ft.

cylindrical tanks which served to damp out pulsations originated from either side of the valve.

Since the pressure variations in the secondary flow line, caused by the pulsations in the primary flow line, were much smaller compared to total flow, and since the secondary flow orifice had a diameter ratio of 66 2/3 per cent it was felt that less capacity was needed to insure steady flow at the secondary flow orifice. Therefore the only surge tank used was a 22 inch x 35 inch steel drum placed between the possible source of pulsations (the test section) and the orifice. This drum served the additional purpose of a stilling chamber to aid in establishing a smooth isotropic entrance flow into the test section.

Throttling Orifice. In order to build up the pressure level of the air supply to the primary line so that a greater range of air flow control might be obtained, an orifice with an area ratio of $66 \frac{2}{3}$ per cent was placed in the six inch line just downstream of the take-off of the 2 inch line. Then just ahead of the 2 inch line entrance to the first surge tank a gate valve was inserted in the line to permit variations in the primary air flow velocity. No provision was made to control the secondary air flow except by variation of total flow through changes in blower speed.

The Pulsator. The source of pulsations in the primary flow was provided by a 2 inch diameter disc type butterfly valve which rotated in the primary flow pipe. The valve completely closed the passage when closed, thus the air flow varied from zero to maximum. The butterfly valve was connected to the sampler rotor shaft through a 1:2 gear ratio. The reduction gear synchronized the sampler valve and butterfly valve since one revolution of the butterfly valve constituted two complete pressure variation cycles.

The frequency of pulsation was adjusted by the variable speed pulley system and was controlled during runs by use of a stroboscope to accurately attain and maintain the desired pulse frequency.

Secondary valve. In order to build up the pressure
back of the air supply to the primary valve a special
valve of the same general type is required, and which will be
given credit of 100% for work done in the air line.
Just downstream of the take-off at the 2 inch line, the
valve of the 2 inch line is connected to the first valve and a
valve was located in the line to permit adjustment in the
valve for this velocity. No provision was made to divert the
secondary air flow except by rotation of the valve
around its own axis.

The primary valve. The manner of adjustment in the
valve was provided by a 2 inch diameter also type
valve which rotated in the primary air pipe. The valve was
rotated about the passage when closed, then the air line
from the primary. The primary valve was connected to the
secondary valve which had a 1/2 inch valve. The secondary
valve was connected to the primary valve and adjusted valve
rotation of the primary valve controlled the secondary
valve rotation.

The frequency of rotation was adjusted by the
valve which rotated and was connected to the
secondary valve which was connected to the primary
valve.

TEST PROCEDURE

Test of Serviceability and Accuracy of Apparatus

After the equipment was assembled, all joints and pressure leads were checked for leaks. The sampling valve was disassembled, inspected, lubricated with a mixture of SAE 10 motor oil and "Molykote", a molybdenum sulfide dry lubricant, and reassembled. A spring pressure of a fixed amount (that pressure which gave a spring constant of $\frac{4\text{lb}}{.020\text{in.}} = 200 \frac{\text{lb}}{\text{in.}}$) was applied and maintained for all tests.

Next the manometer bank connections were checked for leakage by applying a P_a across one air passage of the sampler valve and then rotating the valve ten degrees to close off that passage. Since the valve leaks only while rotating this gave a check on the pressure leads from the valve to the manometers and a check on the proper assembly of the valve.

The valve was then operated through its speed range to check for overheating or other malfunction.

Next, with the engine running the gate valve was adjusted to give the desired ratio of primary velocity to secondary velocity of about two to one, the primary and secondary flows

THEORY

Test of Reliability and Accuracy of Measurement

After the equipment was assembled, all joints and connections were checked for leaks. The working water was then assembled, measured, and poured into a cylinder of 100 cc. and "checked", a replacement of the liquid, and the assembly. A special measure of 1.00 cc. of the liquid was placed in a glass container of 100 cc. and the liquid was measured for all tests.

Each of the two main parts of the apparatus were checked for leaks by applying a Δp across the air passage of the apparatus and then testing the water for leaks in the air passage. When the water level was adjusted to the level of the water in the pressure tank from the air passage and a check on the proper assembly of the water.

The water was then poured through the glass tube.

to check for overpressure or other malfunctions.

Next, with the water running the gas valve was adjusted to give the desired ratio of primary velocity to secondary velocity of about 10 to 1, the primary and secondary flow

being about 200 fps and 100 fps, respectively. The system was checked again for leakage. The effectiveness of the surge tanks was then checked by varying pulsator rpm and noting the effect on the manometers connected to the steady flow sections. In the range of 200 to 300 rpm no evidence of pulsations reaching the steady flow section was noted.

The accuracy of the measuring orifices was checked by computing the flows in the primary and secondary lines and comparing their sums with that flow measured by the orifice at the blower intake. Good agreement was found.

The effect of the length of the tubing connecting the total head tube and the static orifice to the valve was checked by comparing the readings on the manometer board using two sets of pressure leads, one set with the connection as short as possible, the other with 50" leads. No difference was found for these two lengths, consequently the 50" length was used for all readings. This was expected, since the natural resonant frequency for a 50" tube with one end open is on the order of 4000 cycles per minute and is higher for shorter lengths. The tubing used was 3/16 ID, thus not so small as to introduce capillary or extreme friction and attenuation effects.

No drifting or pulsating of the water columns in the manometer bank was observed during any of the check runs.

Tests of the Flow Mixing Region

Before starting the test runs, the engine and valve were run until fully warmed up and running conditions were stabilized. The preliminary runs were made with the engine running at 250 rpm.

To expedite taking readings, a large sheet of paper was placed behind the tubes of the manometer bank and the water column heights marked with pencil. The equilibrium positions of the water columns was marked on each new sheet before the run.

To obtain and maintain the desired pulse frequency of 250 rpm, a stroboscopic tachometer was used. A revolution counter and stopwatch was used for initial setting of the stroboscopes control since its control dial was not calibrated to the desired degree of accuracy.

Control of the airflow was maintained by throttling the driving engine, using the pressure drop across the primary flow measuring orifice as a reference. This value could be maintained constant to within 0.2 in. of water with little difficulty.

The initial run was a calibration run, made with the sampler valve rotating at 250 rpm. For a series of known steady flow values of dynamic pressure, "q", (total pressure minus static pressure) ranging from 3 inches to 16 inches of water, water

Tests of the Water Supply

Water samples were taken at the same time, the water was filtered and the residue was dried at 100°C. The residue was weighed and the difference between the two weights was the weight of the residue.

To determine the amount of water in the residue, a known amount of residue was placed in a dish and the dish was heated in a water bath at 100°C. The residue was dried and weighed and the difference between the two weights was the weight of the water.

The residue was then dried in a desiccator over calcium chloride for 24 hours. A sample of the residue was then weighed and the difference between the two weights was the weight of the water. The residue was then dried in a desiccator over calcium chloride for 24 hours. A sample of the residue was then weighed and the difference between the two weights was the weight of the water.

Control of the water was maintained by the use of a water meter. The water meter was calibrated by the use of a known volume of water. The water meter was then used to measure the volume of water used in the tests.

The total run was a continuous run, with the water being pumped at a constant rate. The water was then pumped at a constant rate for a period of 10 minutes. The water was then pumped at a constant rate for a period of 10 minutes.

levels for all tubes in the manometer bank were marked for each "q" value. Other calibrations were made later in the tests for the purpose of maintaining an accurate calibration of the valve.

The pulsating runs were then made by connecting the butterfly valve to the sampler valve and marking the water levels of the manometer bank tubes for each probe position. The traverse consisted of readings taken each 0.1 inch starting beyond the nozzle centerline and continued through the nozzle centerline position to a distance of 2.5 inches from the centerline. This was accomplished for a series of stations commencing at the nozzle exit and continued to a distance of 39 nozzle diameters downstream.

For comparison with the pulsating flow tests, similar traverses were made with the butterfly valve disconnected from the sampler valve and in the full open position. Here, two traverses were made. One was made at a primary mass flow identical with the primary mass flow existing during the pulsating runs, so that the average velocity from the nozzle should be the same in both conditions. The other traverse was made at an arbitrary value of flow such that the q at the nozzle centerline at the exit was the same as the q at the peak of the cycle of the pulsating runs.

There is no doubt that the Government has been successful in its efforts to bring about a more efficient and economical use of the country's resources.

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DISCUSSION OF RESULTS

The Operating Limits of the Sampling Valve

Wong (11) describes in some detail the limitations, capabilities, and idiosyncracies of the sampler valve. In brief, the major source of error is leakage across the valve which varies with the pressure differential applied across the valve, the direction in which the Δp is applied, the speed of rotation of the valve, and the spring pressure which holds the outer casing against the rotor.

The speed of rotation of the valve affects the leakage in several ways. First, it determines the temperature of the valve which varies the viscosity and sealing power of the lubrication film. This establishes an upper limit of about 300 rpm beyond which the valve overheats rapidly. Low valve speed permits excessive leakage by prolonging the time interval during which leakage from the valve can occur between the successive instants when a particular manometer tube is subjected to its particular Δp at its point in the cycle. This places a lower limit of about 200 rpm upon the valve. Most critical are the dynamic effects of rotation. The valve rotor is not supported independently of the outer casing but rather is supported in a manner similar to a journal bearing; and as in the case of such

a bearing, rotation builds up an air film between the rotor and casing and a circumferential pressure gradient is established which is a function of the speed of rotation.

The valve is thus seen to be very inflexible in its present configuration. However, by remaining within the limits dictated and by removing the maximum number of variables it is possible, by calibration, to remove most of the error. Consequently, for this test a constant spring pressure was applied, a constant rpm was used, the pressure leads were attached with the lower pressure always connected to the narrow end of the rotor, and the valve was calibrated for these particular test conditions by applying a series of known steady Δp values to the rotating valve and marking the readings of the manometer tubes. From these readings a set of calibration curves over the range of 3" to 16" of water were plotted and found to be almost linear, as indicated by Wong. Fig. 16 is a calibration curve included as an example. The other calibration curves are not included since they apply only to this very particular combination of test conditions.

It was found desirable to run all the actual flow tests during the same test period since the calibration of the valve changed from day to day as the amount and condition of lubricant and other factors changed. Check runs made on other days re-

quired that new calibrations be made.

The need for extreme care in controlling the operation of the sampler valve, i.e., the necessity for babying it, the necessity for continuous recalibration, and its inflexibility, greatly reduce the scope of any testing done with it. The latitude of possible test conditions is narrowed by these limitations and the time consumed in obtaining, reducing and rechecking data is enormous. Nevertheless, it seems to be capable of producing reproducible results within its limitations.

The rate of the calibration was not controlled. The calibration curve produced a flow output from zero to full range of a few seconds after the valve was opened.

The data is plotted in terms of standard pressure, $p = p_0 + \rho gh$, where the quantity h is proportional to the square of the velocity, $h \propto v^2$, and pressure variations were then exactly like a velocity plot. Fig. 17 is the equation of a correction plot of h to velocity, as has been mentioned. For a value of h known, as in Fig. 18 and 19, no correction is needed since a velocity scale would be a mere scale of the corresponding h scale. The velocities and h values which are indicated

The Mixing Region Flow Data

For the purpose of definition, the nozzle exit is taken as the origin of coordinates used in plotting the data. The distance along the nozzle centerline is denoted by $\frac{x}{D}$, positive downstream, in nozzle diameters. The lateral distance from the nozzle centerline is $\frac{y}{D}$. Thus $\frac{y}{D} = 0.5$ is the boundary of the nozzle and $\frac{x}{D} = 0$ is the station at the nozzle exit.

The value of 250 rpm used in these tests was arbitrary, prescribed by the limitations of the sampler valve, it not being practicable in the preliminary investigation to consider the effects of pulse frequency as a parameter.

The form of the pulsation wave was not controlled. The butterfly valve produces a flow varying from zero to maximum, of a form somewhat similar to harmonic wave shape.

The data is plotted in terms of dynamic pressure, $q = p_o - p_s = \frac{1}{2} \rho \frac{u^2}{\epsilon_o}$. Since the quantity q is proportional to the square of the velocity, it shows pressure variations more distinctly than a velocity plot. Fig. 17 in the appendix is a conversion plot of q to velocity, at the test conditions. For a ratio of q values, as in Figs. 14 and 15, no conversion is needed since a velocity ratio equals the square root of its corresponding q ratio. Key velocities and velocity ratios are indicated

on most plots.

Fig. 3 to Fig. 12 are plots of the dynamic pressure versus manometer tube, which is, in effect, a standing wave of the dynamic pressure cycle produced by one cycle of the butterfly valve. The butterfly valve full-open position corresponded to that position of the sampler valve which indicated on tube number 27. However, the peak of the q cycle is seen to occur some 110° later in the cycle, at about tube 2. At 250 rpm, this corresponds to about 73 milliseconds delay between the production and recording of a particular value. The delay is a constant value since the standing wave showed no phase shifting but held its position very steadily. The complete cause of the delay value was not ascertained since it amounts to an average velocity between butterfly valve and sampler valve of $\frac{6.25 \text{ ft}}{.073 \text{ sec.}} = 86 \text{ ft/sec}$. This is much less than the velocity at which the changed ratio of p_0/p_s due to throttling might be expected to travel and very much less than the local velocity of sound, at which approximate speed small pressure variations would travel. A possible explanation is that the major portion of the phase difference was due to the nature of the production of the pulsations. It is possible that the peak velocity through the butterfly did not occur exactly at the full open position. If most of the reduction in mass flow occurred when the butterfly was within,

say, 30° of the closed position, then the minimum velocity would occur when the mass flow was at a low level and the flow area was increasing, as at the 45° to 55° position beyond the closed position. Similarly the peak velocity would occur when the mass flow was at a high level and the flow area being reduced, as at about the opposite part of the cycle. This would place the peak velocity at about 50° past the full open position of the butterfly, or about 100° past tube 27, i.e., at tube 1 of the sampler.

The important fact relating to this investigation was that the sampler measured a standing wave which did not drift or pulsate.

The wave form in the pulsating jet is seen to be fairly regular. The scatter of data points is less than was expected, and curves were plotted through the points where evidence of cyclic variations occurred so that resonant vibrations, if any, or other cyclic irregularities might be discerned. However, no consistent evidence was found that sympathetic vibrations were introduced into the system as had been the case in the work of Becker and Wong.

At the trough of each wave there was evidence of rapid pressure irregularities which it is believed were associated with the flow through the valve when the valve was very near the actual

closed position.

Pressure pulses were transmitted to the secondary flow region, even at station $\frac{x}{D} = 0$, causing a q variation which averaged 0.5 in. of water. This was transmitted to the secondary flow outside the jet mixing region as a variation in static pressure. To confirm this, cyclic measurements of $p_o - p_{atm}$ and $p_s - p_{atm}$ were made at $\frac{x}{D} = 0$. The value of $p_s - p_{atm}$ was found to vary from -0.23 in. H_2O to -0.68 in. H_2O , a total variation of 0.45 in. H_2O .

The Kiel tube would not have been a suitable instrument for total head measurements had the flow configuration been such that flow reversals occurred. The check mentioned in the previous paragraph showed that total pressure varied smoothly from a value of about 15 in. H_2O to a minimum of about 9 in. at the trough of the cycle, at the nozzle centerline at $\frac{x}{D} = 0$. The minimum was about 5.75 in. H_2O at the edge of the jet and about 3 in. H_2O in the secondary flow. At no time did it approach zero. Thus the possibility of flow reversal was discounted.

Curves for successive $\frac{x}{D}$ stations show that a slight phase shift seems to be occurring as the flow moves downstream. The peak of waves for station $\frac{x}{D} = 12$ and beyond occurs closer to tube 3 than tube 2.

aligned position.

Pressure values were measured on the boundary line
 before, then at station $\frac{1}{2}$ in, between a 2 inch and 4 inch
 apart and in the center. This was repeated on the boundary
 line inside the jet which means at a distance of 10 to 12
 mm. to outside hole, specific measurements = $\frac{1}{2}$ in - 10 mm
 at - 10 mm were made at $\frac{1}{2}$ in = 0. The value of $\frac{1}{2}$ in - 10 mm
 to give from 0.15 to 0.25 in. 10 mm. 10 mm. 10 mm. 10 mm. 10 mm.
 0.25 in. 10 mm.

The first run made was with a certain pressure
 for 1000 and measurements for the first 1000 mm. 1000 mm.
 (10) The pressure was 1000 mm. 1000 mm. 1000 mm. 1000 mm.
 the pressure was 1000 mm. 1000 mm. 1000 mm. 1000 mm.
 value of 1000 mm. 1000 mm. 1000 mm. 1000 mm. 1000 mm.
 length of the hole, at the middle was 1000 mm. 1000 mm.
 hole was 1000 mm. 1000 mm. 1000 mm. 1000 mm. 1000 mm.
 1000 mm. 1000 mm. 1000 mm. 1000 mm. 1000 mm.
 from the position of the jet was 1000 mm.

When the pressure $\frac{1}{2}$ in. 10 mm. 10 mm. 10 mm. 10 mm.
 these values were 1000 mm. 1000 mm. 1000 mm. 1000 mm.
 The value of 1000 mm. 1000 mm. 1000 mm. 1000 mm. 1000 mm.
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Fig. 13 and Fig. 14 are cross-plots from points from tubes 2, 13, and 17 in the earlier curves and from the steady flow data. They are profiles of dynamic pressure showing the variation of q with $\frac{x}{D}$ and with $\frac{y}{D}$. The above mentioned tubes were chosen so as to have profiles of the peak, the minimum, and an intermediate portion of the cycle. That intermediate value was chosen which had a q_0 equal to that of the steady flow traverse which had been made with a primary mass flow equal to the primary mass flow of the pulsating flow. This permitted a direct comparison of a pulsating flow and a steady flow which had the same mass flow and same average velocities.

It is noted that due to the inability to control the secondary air flow and the fact that less blower speed was necessary in the steady flow case to produce identical mass flows for pulsating and for steady flows, the secondary flow was less for the steady flow case. However, the change was small, the ratio of secondary velocity to primary velocity being 0.45 in the steady flow case and 0.53 for pulsating flow, the ratio of 0.5 having been initially selected as the approximate value desired for this investigation.

Fig. 14 and Fig. 15 make it seem that the velocity profile of the jet at the nozzle exit was not very flat. However,

[illegible][illegible]

remembering that this a plot of q rather than velocity, one sees that the corresponding velocity profile would be much flatter. The edge velocity, if computed, is seen to be 75% of the maximum velocity, which is flatter than the so called laminar flow profile. Laminar flow was not desired in this test, and with the disturbance created by the butterfly and the existing Reynolds number of 41,000 the primary flow is distinctly turbulent.

The profiles show two things clearly, that a marked similarity exists between the pulsating and steady cases, the pulsating flow having a slightly flatter initial profile, and that the profile in each case shows signs of approaching the flat condition at about $\frac{x}{D} = 21$. At this station, the ratio of the maximum velocity to secondary velocity is:

	u_o/u_s
Pulsating, maximum	1.20
Pulsating, minimum	1.15
Pulsating, intermediate	1.12
Steady, intermediate	1.19

By station $\frac{x}{D} = 27.5$, the ratios had become:

	u_o/u_s
Pulsating, maximum	1.10
Pulsating, minimum	1.10
Pulsating, intermediate	1.06
Steady, intermediate	1.10

By station $\frac{x}{D} = 39$, in each case, the velocity profile was not apparent to the measuring equipment. This is not in ac-

measured in the first 100 ft of the borehole, and was
 about 100 ft. The velocity was about 100 ft/sec.
 The velocity, it appears, is about 100 ft/sec of the
 velocity, and is rather low for an elastic material. The
 elastic modulus was not determined in this case, and with the
 observation made by the velocity and the elastic modulus
 number of 10,000 the velocity is about 100 ft/sec.

The profile was two elastic, the velocity was
 similar to that between the profile and the elastic
 modulus. The profile was similar to that of the profile,
 and the profile is not very different from the profile of
 the profile of the profile. The velocity was about 100 ft/sec.

Two elastic modulus, the velocity was about 100 ft/sec.

μ/ρ	μ/ρ
1.10	1.10
1.11	1.11
1.12	1.12
1.13	1.13

At station 100 ft, the velocity was about 100 ft/sec.

μ/ρ

μ/ρ	μ/ρ
1.10	1.10
1.11	1.11
1.12	1.12
1.13	1.13

At station 100 ft, the velocity was about 100 ft/sec.
 The velocity was about 100 ft/sec. The velocity was about 100 ft/sec.

cordance with the work of Shapiro and Forstall (6) who found that for steady flow a "slope coefficient", a measure of the normalized profile slope was constant as far downstream as 140 diameters. However, since velocity along the axis beyond the core of potential flow decreases with increasing $\frac{x}{D}$, more reliable and sensitive measuring equipment than the sampler valve will be necessary to carry the investigation further downstream than was done in this test.

Despite the fact that this investigation was fundamentally concerned with the direct comparison of a steady jet and a pulsating jet having identical configurations except for steadiness and non-steadiness, it was desired, for purposes of evaluating the type of steady flow actually attained and evaluating the accuracy of measurement, to compare the mixing region characteristics with those defined by previous investigations. One of the most useful presentations of experimental data and empirical relations for jet flows of the nature present in this investigation is that by Forstall and Shapiro (6). Among their findings are that:

- (1) All normalized velocity (and concentration) profiles downstream of the core of potential flow have strikingly similar shapes which are substantially independent of $\frac{x}{D}$. Furthermore, these shapes may be represented rather well by several

mathematical expressions, a cosine curve being the most similar.

(2) Beyond the end of the potential core, the value of velocity (and concentration) varies inversely with x , irrespective of the velocity ratio, λ .

(3) Some empirical relations based on their experimental data are:

(a) The $\frac{x}{D}$ value for the end of the potential core:

$$L = 4 + 12 \lambda$$

(b) Velocity decay downstream of the potential core, $(\frac{x}{D} > L)$:

$$\frac{u - u_s}{u_0 - u_s} = \frac{L}{\frac{x}{D}}$$

A comparison of the experimental data of this experiment with the above empirical relations is made in Fig. 14-c and Fig. 14-d. Very close agreement was obtained with the empirical rate of velocity decay, indicated by the 1:1 slope of the logarithmic plots. The exact actual position of the end of the potential core is of course indeterminable experimentally because a transition region exists rather than a sharp boundary, as indicated by the lack of a sharp break in the experimental plot. However, the approximate position can be found by continuing the straight line velocity plots to their intersections. This produces an "L" position about 1.5 diameters less than the em-

condition (1) and (2) are satisfied, a sufficient condition

for (3) is that $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (2)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (3)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (4)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (5)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (6)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (7)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (8)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (9)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (10)

$$\frac{1}{t} \int_0^t f(s) ds = \frac{1}{t} \int_0^t f(s) ds$$

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (11)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (12)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (13)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (14)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (15)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (16)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (17)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (18)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (19)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (20)

and $\lim_{t \rightarrow \infty} \frac{1}{t} \int_0^t f(s) ds = 0$ (21)

pirical value for the steady jet and about 2.5 diameters less for the pulsating jet. This is considered good agreement.

The velocity parameter $\frac{u-u_s}{u_o-u_s}$ was chosen to reduce all plots to the same scale, and to eliminate the effect of dissimilar secondary flows. This indicates the degree to which the jet retains its original excess of velocity over the secondary flow, a value of $\frac{u-u_s}{u_o-u_s} = 0$ thus indicating complete velocity mixing. A similar parameter was used for the q plots described later.

To compare shapes, the profiles were made dimensionless and normalized by plotting $\frac{u-u_s}{u_o-u_s}$ versus $\frac{r}{r_m}$. When fully normalized in this manner, the profiles (Fig. 14-a) at $\frac{x}{D} = 12$ and $\frac{x}{D} = 21$ (downstream of the potential core) are seen to be almost identical at both stations for the intermediate value steady and pulsed flows, except for a spreading near the base of the profile. Forstall and Shapiro, in their more carefully controlled experiment, encountered the spread to a lesser degree, it being caused by the poor experimental accuracy possible in determining $(u-u_s)$ near the edge of the jet.

Other profiles could not be checked because those at $\frac{x}{D}$ less than 12 were within the potential core and those at $\frac{x}{D}$ greater than 21 offered too few distinct points for a valid determination of r_m . However, these two profiles are considered

physical value for the steady state and the value for the
for the following part. This is considered as a physical

The velocity parameter $\frac{1}{10^{10}}$ was chosen to ensure all
fields for the same value, and to minimize the value of the
for secondary flow. This indicates the system to which the
velocity the original value of velocity over the secondary flow
a value of $\frac{1}{10^{10}} = 0$ and indicating the velocity value
a similar parameter was used for the same purpose later.

In many cases, the profiles were used to determine
the and corrected for the effect of the velocity value $\frac{1}{10^{10}}$ on the
velocity in this manner, the profiles (10-11) at $\frac{1}{10^{10}} = 10$
and $\frac{1}{10^{10}} = 21$ (however, of the secondary flow) are seen to be
almost identical at both ends for the same velocity value
steady and pulsed flow, except for a variation over the part
of the profile. General and specific, in which the velocity
control system, considers the speed of a laser the
flow, it is not called by the flow experimental system, but
the is determined (10-11) over the end of the flow.

Other profiles could not be obtained because of the
 $\frac{1}{10^{10}}$ flow rate in which the velocity value was chosen as $\frac{1}{10^{10}}$
However, the 11 others are the velocity profile for which the
determination of $\frac{1}{10^{10}}$ however, these are profiles are calculated

the most significant since the unnormalized velocity profiles differ markedly between the two stations, the profile at $\frac{x}{D}$ being that one at which definite flattening of the profile, is first observed.

For direct comparison, a cosine curve is also shown and gives good agreement in the region where experimental accuracy was good.

The previous comparisons then would indicate that the experimental accuracy of this investigation was better in the regions where larger pressure differentials being measured than near the edges of the jet where the pressure differentials were smaller. However, the good agreement of the data with that of previous investigators indicates that the accuracy of measurements was reasonably good.

To actually picture the jet mixing region, Fig. 15-a through Fig. 15-e were plotted. These plots delineate lines of constant q , utilizing the parameter $\frac{q-q_s}{q_o-q_s}$.

The following table, from values in Fig. 15, compares the points at which the centerline flow might be considered mixed to various degrees:

The next experiment was the investigation of the effect of the concentration of the solution on the rate of reaction. The results are given in Table II. It was found that the rate of reaction increases with the concentration of the solution. The results are given in Table II.

The effect of temperature on the rate of reaction was also investigated. The results are given in Table III. It was found that the rate of reaction increases with the temperature. The results are given in Table III.

The effect of the presence of a catalyst on the rate of reaction was also investigated. The results are given in Table IV. It was found that the rate of reaction increases with the presence of a catalyst. The results are given in Table IV.

To determine the order of reaction, the rate of reaction was measured at different concentrations of the reactants. The results are given in Table V. It was found that the reaction is first order with respect to the concentration of the reactants. The results are given in Table V.

The following table gives the values of the rate constant k at different temperatures. The results are given in Table VI. It was found that the rate constant increases with the temperature. The results are given in Table VI.

$\frac{x}{D}$ Values for Mixing 85%, 68% and 55% Completed:

	$\frac{u-u_s}{u_o-u_s}$		
	0.15	0.32	0.45
	x/D	x/D	x/D
Pulsating, maximum	35.0	24.5	19.0
Pulsating, minimum	37.0	27.0	18.3
Pulsating, intermediate	36.0	24.0	18.4
Steady, intermediate	35.0	21.0	17.1
Steady, maximum	34.0	23.0	16.0

From the above, the conclusion might be drawn that the steady flow mixes slightly more rapidly than the pulsating flow. However, the facts that the accuracy of the absolute levels of pressure measurement by the sampler value is not known, and that the measurements of the steady flow values are approximate to the extent that flow turbulence caused a manometer water level fluctuation of up to 0.5 inch of water would lead to a more reasonable conclusion that the velocity mixing in the steady flow case and the pulsating case differ in no appreciable degree, consistent with the control exercised in this investigation.

CONCLUSIONS AND RECOMMENDATIONS

With respect to the sampling valve, the conclusions to be drawn are:

1. It can be utilized in investigations of this nature in its present configuration, but at the cost of considerable time expended in calibration and rechecking of data.

2. The valve is extremely inflexible. Its range of operation could be extended and its accuracy increased by eliminating the bearing action of the rotor and by providing a means of cooling the rotor and casing.

3. When properly calibrated and used within its limitations it can provide reproducible data. However, the accuracy of the absolute level of pressure measurements is not definitely known, and the effects of pulsation form and frequency, and of the pressure differential applied across the valve, upon the accuracy of measurement could well be a subject of further investigation.

With respect to the test equipment, it is recommended that a more flexible, simpler design patterned after that of Forstall and Shapiro (6) in which the secondary flow is drawn through the test section rather than blown through would be adaptable to the turbine test cell layout of the Mechanical En-

CONCLUSIONS AND RECOMMENDATIONS

With respect to the second phase, the conclusion is

as given above:

1. It has been shown in the investigation of this phase

in the present investigation, but in the case of considerable

time expended in collection and recording of data.

2. The value is extremely important. The value of

operation could be extended and the economy increased by eff-

fecting the moving action of the piston and by providing a means

of cooling the piston and cylinder.

3. When properly utilized and used with the

limitations it can provide considerable data. However, the de-

gree of the absolute level of pressure measurement is not

definitely known, and the effects of pressure loss and leak-

age, and of the pressure differential applied across the valve,

upon the accuracy of measurement would well be a subject of fur-

ther investigation.

With respect to the last equipment, it is recommended

that a new flexible, lighter design be adopted after that of

Therrell and Shapiro (4) in which the indicator line is drawn

through the test section right into the cylinder where it

is applicable to the future test cell layout of the mechanical in-

gineering Department, and would provide for smoother flow entrance into the test section and permit more accurate determination of the velocity profile in the critical regions where mixing is almost complete.

The sampler valve must be redesigned, if possible, or a substitute method of measuring varying pressures be applied before tests beyond the scope of this preliminary investigation can be prosecuted to any degree of success.

In this investigation of the mixing of a pulsating air jet in a steady secondary airstream it was found that:

1. There was no appreciable difference between the velocity mixing region of a cool, isothermal pulsating jet and mixing region of a steady flow jet of similar configuration, at a Reynolds number of 41,000 and $\lambda = 0.5$, when pulsations were formed by regular interruption of the flow at 250 cpm.

2. There was good agreement with the findings of other investigations previously made for the steady flow case that:

- (a) The fully normalized velocity profiles downstream of the potential core are of the same shape, irrespective of the value of $\frac{x}{D}$ and closely resemble a cosine curve.

- (b) The centerline velocity, downstream of the

...the ...
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The ...
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1. There are ...
...the ...
...the ...
...the ...
...the ...

2. There are ...
...the ...

(a) The ...
...the ...
...the ...

(b) The ...

potential core, decays in direct proportion to the value of $\frac{x}{D}$.

(c) The location of the end of the potential core at the centerline is closely defined by the empirical relation

$$L = 4 + 12 \lambda$$

3. The close agreement of the data of this investigation in the region where pressure differences were large indicate a reasonably good level of accuracy. The inability to accurately define the outer edges of the jet, where the pressure differences are smaller indicate the need for more closely controlled pulsed flow investigations utilizing measuring equipment more sensitive than the mechanical sampling valve used in the experiment.

4. Based on the ratio of the jet velocity in excess of the secondary flow to the original jet velocity in excess of the secondary flow, $\frac{u-u_s}{u_0-u_s}$, the centerline flow was considered 85% mixed at an average $\frac{x}{D} = 36$ for both the steady and pulsating cases, was 68% mixed at an average $\frac{x}{D} = 24$, and was 45% mixed at an average $\frac{x}{D} = 18$. In both cases the steady flow jets appeared to mix slightly sooner than the pulsating jet, but the accuracy of the data does not justify drawing a firm conclusion to that effect.

5. It is recommended that further investigations of this nature be made to check the effects of variation in pulse frequency, of pulsation form, of velocity ratio, λ , and of Reynolds number, upon the nature of the mixing region of a pulsating jet.

It is believed that the use of high speed photography coupled with Schlieren and/or shadowgraph flow visualization techniques might prove a profitable avenue of investigation.

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2. It is recommended that further investigations of this nature be made to cover the whole of the island in order to determine the frequency of pollution from the various sources, and to determine the nature of the damage caused by a visit to the island.

It is believed that the use of the word "pollution" is not correct in this context and that the word "contamination" is more appropriate as it gives a more definite sense of the word.

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LIST OF SYMBOLS

Indices

- (1) radial direction, inches
- (2) axial direction from center axis, in direction of end of tubular arm
- x direction, side of the eye
- y direction, side of the eye
- z direction, inches
- θ angular velocity, where velocity is assumedly positive at smaller and smaller values of θ
- ϕ direction velocity
- ψ axial direction from center axis, inches
- χ internal direction from center axis, inches

APPENDIX

Abbreviations

1. θ angular velocity
2. ϕ direction velocity
3. ψ axial direction from center axis, inches
4. χ internal direction from center axis, inches

Other Abbreviations

- A. (approximate) value
- B. (approximate) value
- C. (approximate) value
- D. (approximate) value
- E. (approximate) value
- F. (approximate) value
- G. (approximate) value
- H. (approximate) value
- I. (approximate) value
- J. (approximate) value
- K. (approximate) value
- L. (approximate) value
- M. (approximate) value
- N. (approximate) value
- O. (approximate) value
- P. (approximate) value
- Q. (approximate) value
- R. (approximate) value
- S. (approximate) value
- T. (approximate) value
- U. (approximate) value
- V. (approximate) value
- W. (approximate) value
- X. (approximate) value
- Y. (approximate) value
- Z. (approximate) value

TABLE

LIST OF SYMBOLS

Letters: The symbols in the tables below are defined as follows:

- D Nozzle diameter, inches
- L Axial distance from nozzle exit, in diameters, of end of potential core
- p Pressure, psia or in. H₂O
- q Dynamic pressure, psi or in. H₂O
- r Radius, inches
- r_m Radius, inches, where velocity is arithmetic average of secondary and centerline values at any x.
- u Axial flow velocity at any point
- x Axial distance from nozzle exit, inches
- y Lateral distance from nozzle centerline, inches

Subscripts:

- j Jet
- o Total as in p_o; maximum as in q_o or u_o.
- p Primary flow
- s Static as in p_s; secondary flow as in q_s or u_s.

Greek Letters:

- Δ Differential value
- μ Absolute Viscosity $\frac{\text{lb}}{\text{ft-sec}}$
- ρ Density, $\frac{\text{lb}}{\text{ft}^3}$
- λ Ratio of secondary velocity to centerline velocity at $\frac{x}{D} = 0$.

Radio of secondary winding is $\frac{1}{2}$ of primary winding	1
Turns of $\frac{1}{2}$ primary	2
Secondary winding is $\frac{1}{2}$ of primary	3
Ratio of secondary winding is $\frac{1}{2}$ of primary winding	4

1. Air Flow Measurement and Calculation

The orifices in the system have been installed in accordance with A.S.M.E. Code. The equation used to find the mass flow was:

$$W = 0.668 A_2 K E Y \sqrt{\rho \Delta p}$$

where

W = Mass flow in lb per sec.

A_2 = Throat area in square in.

K = Flow coefficient

E = Area multiplier for thermal expansion of the orifice plate.

Y = Empirical expansion factor

ρ = Upstream density of flowing air

Δp = Pressure drop across the orifice plate in psi

For a typical example of the determination of the mass flow with an orifice plate, see Example 2, page 7, ref. (9).

Calculation of Reynolds Number

2. The Reynolds number was calculated from the following equation:

$$N_R = \frac{\rho u D}{\mu}$$

3. The natural frequency of the tube with one end closed is computed from the following equation:

$$f = \frac{a}{4L}$$

TABLE I

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q , IN INCHES OF WATER

$$\frac{x}{D} = 0$$

$\frac{y}{D}$, Distance from Nozzle Center, inches

Degrees	0	0.1	0.2	0.3	0.4	0.5	1.0 to 2.5
10	15.70	15.15	14.85	14.10	11.85	9.70	3.55
20	15.80	15.30	15.00	14.10	11.95	9.75	3.40
30	15.60	15.10	14.80	13.95	11.90	9.65	3.60
40	15.35	14.85	14.60	13.60	11.40	8.35	3.40
50	14.95	14.40	14.25	13.30	11.25	9.10	3.75
60	14.50	13.95	13.80	12.80	10.80	8.65	3.60
70	14.20	13.65	13.40	13.00	10.55	8.50	3.65
80	13.80	13.25	13.05	12.20	10.30	8.30	3.75
90	13.50	13.00	12.75	11.90	10.00	8.20	3.55
100	12.85	12.30	12.15	11.30	9.40	7.70	3.50
110	12.50	11.90	11.75	11.00	9.20	7.65	3.40
120	12.05	11.55	11.30	10.50	8.60	7.00	3.30
130	11.40	10.85	10.70	9.85	8.10	6.50	3.25
140	10.90	10.40	10.25	9.54	7.70	6.05	3.15
150	10.55	10.05	9.85	9.15	7.40	5.90	3.15
160	10.15	9.62	9.49	8.75	7.21	5.72	2.90
170	9.95	9.40	9.30	8.60	6.90	5.40	3.05
180	10.13	9.62	9.40	8.75	7.16	5.70	3.00
190	10.45	9.80	9.65	8.80	7.20	5.70	2.70
200	10.60	9.90	9.85	9.00	7.40	5.90	2.85
210	10.70	10.00	10.00	9.10	7.45	6.00	2.85
220	11.30	11.00	10.40	9.55	7.95	6.45	2.90
230	11.80	11.10	10.95	10.10	8.40	6.80	3.50
240	12.30	11.45	11.40	10.40	8.70	7.10	3.80
250	12.60	11.85	11.75	10.75	9.00	7.40	3.85
260	13.05	12.20	12.10	11.10	9.40	7.60	3.80
270	13.40	12.50	12.40	11.45	9.70	8.00	3.75
280	13.90	13.00	12.85	11.85	10.00	8.20	3.70
290	14.10	13.20	13.10	12.10	10.10	8.40	3.60
300	14.50	13.65	13.40	12.20	10.30	8.45	3.55
310	14.90	14.00	13.90	12.80	10.80	8.70	3.70
320	15.10	14.45	14.30	13.20	10.90	9.03	3.60
330	15.30	14.40	14.40	13.25	11.10	9.10	3.45
340	15.35	14.55	14.45	13.40	11.40	9.40	3.55
350	15.50	14.60	14.60	13.55	11.45	9.50	3.7
360	17.00	14.95	14.95	13.80	11.70	9.65	

$$\phi = \frac{2\pi}{3}$$

TABLE II

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q , IN INCHES OF WATER

$$\frac{x}{D} = 3$$

Distance from Nozzle Center, inches

Degrees	0.0	0.2	0.3	0.4	0.5	0.6	0.7 to 2.5
10	15.20	14.50	13.25	10.75	7.10	4.00	3.45
20	15.45	14.75	13.40	10.90	7.05	4.05	3.50
30	15.40	14.70	13.25	10.80	7.05	4.00	3.50
40	15.05	14.35	12.95	10.50	6.90	3.90	3.50
50	14.70	14.00	12.55	10.25	6.65	3.85	3.50
60	14.30	13.60	12.30	9.85	6.45	3.85	3.50
70	14.00	13.70	11.90	9.60	6.30	3.85	3.50
80	13.45	12.75	11.50	9.45	6.20	3.85	3.50
90	13.10	12.40	10.90	9.20	6.05	3.80	3.50
100	12.70	12.00	10.75	8.65	5.80	3.60	3.40
110	12.30	11.60	10.15	8.45	5.55	3.50	3.25
120	11.85	11.15	10.00	8.05	5.35	3.40	3.25
130	11.15	10.50	9.55	7.80	5.10	3.25	3.05
140	10.80	10.00	9.25	7.60	5.00	3.25	3.10
150	10.35	9.70	8.70	7.25	4.80	3.05	2.95
160	10.00	9.30	8.55	7.15	4.70	3.00	2.95
170	9.70	9.10	8.20	6.85	4.60	3.15	3.00
180	10.00	9.20	8.40	7.10	4.70	3.50	3.40
190	10.15	9.45	8.35	6.95	4.65	3.45	3.30
200	10.20	9.50	8.30	6.85	4.55	3.50	3.20
210	10.35	9.65	8.45	6.90	4.55	3.55	3.10
220	10.60	9.90	8.65	7.15	4.80	3.50	3.25
230	11.05	10.35	9.10	7.60	5.00	3.50	3.40
240	11.65	10.95	9.55	8.00	5.30	3.50	3.30
250	11.80	11.10	9.90	8.15	5.45	3.65	3.45
260	12.35	11.65	10.30	8.55	5.65	3.70	3.50
270	12.70	12.00	10.55	8.75	5.85	3.75	3.50
280	12.90	12.20	10.80	9.05	5.93	3.80	3.45
290	13.40	12.60	11.35	9.35	6.15	3.80	3.50
300	13.80	13.10	11.50	9.40	6.25	3.85	3.45
310	14.10	13.40	11.90	9.80	6.40	3.85	3.50
320	14.30	13.60	12.00	10.05	6.40	3.80	3.45
330	14.50	13.80	12.55	10.25	6.60	3.85	3.50
340	14.80	14.10	12.70	10.35	6.55	3.80	3.50
350	14.90	14.20	12.80	10.60	6.75	3.85	3.50
360	15.10	14.40	12.90	10.65	6.80	3.85	3.45

TABLE II

RELATIVE RISK

RELATIVE RISK OF DEATH BY CAUSE OF DEATH

$$R = \frac{a}{b}$$

RELATIVE RISK OF DEATH BY CAUSE OF DEATH

Relative Risk	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0
0.0	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00

TABLE III

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q , IN INCHES OF WATER

$$\frac{x}{D} = 5$$

Distance from Nozzle Center, inches

Degrees	0.0	0.1	0.2	0.3	0.4	0.5	0.8 to 2.5
10	14.10	13.60	12.60	9.95	7.50	5.00	3.45
20	14.25	13.85	12.70	10.00	7.50	5.05	3.50
30	14.20	13.75	12.65	9.95	7.50	5.20	3.60
40	13.90	13.35	12.30	9.70	7.25	4.95	3.45
50	13.60	13.10	12.05	9.50	7.10	4.95	3.55
60	13.20	12.65	11.60	9.10	6.70	4.80	3.55
70	13.00	12.35	11.40	9.00	6.85	4.75	3.60
80	12.60	12.15	11.20	8.85	6.65	4.80	3.70
90	12.30	11.80	10.90	8.60	6.50	4.70	3.55
100	11.70	11.30	10.30	8.15	6.15	4.40	3.33
110	11.35	11.00	10.10	8.05	6.25	4.25	3.25
120	11.00	10.60	10.55	7.60	5.65	4.10	3.20
130	10.35	10.00	9.10	7.05	5.20	4.02	3.10
140	10.00	9.65	8.80	6.70	5.00	3.90	3.10
150	9.70	9.30	8.55	6.55	4.80	3.69	3.00
160	9.32	8.95	8.21	6.45	4.70	3.40	3.00
170	9.00	8.60	7.90	6.10	4.45	3.28	2.95
180	9.25	8.95	8.30	6.50	5.10	3.50	3.00
190	9.10	8.70	7.90	6.10	4.61	3.50	3.00
200	9.25	8.85	8.00	6.30	4.80	3.59	3.00
210	9.40	8.95	8.10	6.30	4.80	3.42	2.79
220	9.94	9.51	8.62	6.85	5.25	3.80	3.06
230	10.35	10.00	9.05	7.20	5.40	4.10	3.31
240	10.70	10.25	9.30	7.40	5.60	4.20	3.30
250	11.15	10.75	9.75	7.70	5.85	4.20	3.49
260	11.45	11.05	10.05	8.05	6.20	4.50	3.50
270	11.90	11.40	10.30	8.25	6.35	4.70	3.61
280	12.30	11.75	10.65	8.50	6.50	4.80	3.50
290	12.45	11.90	10.80	8.60	6.45	4.75	3.51
300	12.80	12.25	11.10	8.70	6.60	4.85	3.50
310	13.25	12.75	11.50	9.10	6.75	4.90	3.56
320	13.40	12.95	11.75	9.25	6.96	5.05	3.60
330	13.65	13.05	12.00	9.40	7.00	5.00	3.55
340	13.85	13.15	12.20	9.70	7.25	5.10	3.60
350	13.90	13.25	12.30	9.80	7.45	5.20	3.60
360	13.90	13.35	12.35	9.80	7.50	5.10	3.48

TABLE III

WATER VAPOR PRESSURE

WATER VAPOR PRESSURE IN mm. Hg. vs. TEMPERATURE IN °C.

$$p = \frac{S}{V}$$

WATER VAPOR PRESSURE IN mm. Hg.

TEMPERATURE °C.	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
0.0	0.611	0.615	0.619	0.623	0.627	0.631	0.635	0.639
0.5	0.615	0.619	0.623	0.627	0.631	0.635	0.639	0.643
1.0	0.619	0.623	0.627	0.631	0.635	0.639	0.643	0.647
1.5	0.623	0.627	0.631	0.635	0.639	0.643	0.647	0.651
2.0	0.627	0.631	0.635	0.639	0.643	0.647	0.651	0.655
2.5	0.631	0.635	0.639	0.643	0.647	0.651	0.655	0.659
3.0	0.635	0.639	0.643	0.647	0.651	0.655	0.659	0.663
3.5	0.639	0.643	0.647	0.651	0.655	0.659	0.663	0.667
4.0	0.643	0.647	0.651	0.655	0.659	0.663	0.667	0.671
4.5	0.647	0.651	0.655	0.659	0.663	0.667	0.671	0.675
5.0	0.651	0.655	0.659	0.663	0.667	0.671	0.675	0.679
5.5	0.655	0.659	0.663	0.667	0.671	0.675	0.679	0.683
6.0	0.659	0.663	0.667	0.671	0.675	0.679	0.683	0.687
6.5	0.663	0.667	0.671	0.675	0.679	0.683	0.687	0.691
7.0	0.667	0.671	0.675	0.679	0.683	0.687	0.691	0.695
7.5	0.671	0.675	0.679	0.683	0.687	0.691	0.695	0.699
8.0	0.675	0.679	0.683	0.687	0.691	0.695	0.699	0.703
8.5	0.679	0.683	0.687	0.691	0.695	0.699	0.703	0.707
9.0	0.683	0.687	0.691	0.695	0.699	0.703	0.707	0.711
9.5	0.687	0.691	0.695	0.699	0.703	0.707	0.711	0.715
10.0	0.691	0.695	0.699	0.703	0.707	0.711	0.715	0.719
10.5	0.695	0.699	0.703	0.707	0.711	0.715	0.719	0.723
11.0	0.699	0.703	0.707	0.711	0.715	0.719	0.723	0.727
11.5	0.703	0.707	0.711	0.715	0.719	0.723	0.727	0.731
12.0	0.707	0.711	0.715	0.719	0.723	0.727	0.731	0.735
12.5	0.711	0.715	0.719	0.723	0.727	0.731	0.735	0.739
13.0	0.715	0.719	0.723	0.727	0.731	0.735	0.739	0.743
13.5	0.719	0.723	0.727	0.731	0.735	0.739	0.743	0.747
14.0	0.723	0.727	0.731	0.735	0.739	0.743	0.747	0.751
14.5	0.727	0.731	0.735	0.739	0.743	0.747	0.751	0.755
15.0	0.731	0.735	0.739	0.743	0.747	0.751	0.755	0.759
15.5	0.735	0.739	0.743	0.747	0.751	0.755	0.759	0.763
16.0	0.739	0.743	0.747	0.751	0.755	0.759	0.763	0.767
16.5	0.743	0.747	0.751	0.755	0.759	0.763	0.767	0.771
17.0	0.747	0.751	0.755	0.759	0.763	0.767	0.771	0.775
17.5	0.751	0.755	0.759	0.763	0.767	0.771	0.775	0.779
18.0	0.755	0.759	0.763	0.767	0.771	0.775	0.779	0.783
18.5	0.759	0.763	0.767	0.771	0.775	0.779	0.783	0.787
19.0	0.763	0.767	0.771	0.775	0.779	0.783	0.787	0.791
19.5	0.767	0.771	0.775	0.779	0.783	0.787	0.791	0.795
20.0	0.771	0.775	0.779	0.783	0.787	0.791	0.795	0.799

TABLE IV

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q , IN INCHES OF WATER

$$\frac{x}{D} = 9$$

Distance from Nozzle Center, inches

Degrees	0.0	0.1	0.2	0.5	0.7	0.9 to 2.5
10	10.95	10.60	9.25	5.10	3.80	3.55
20	11.25	10.75	9.45	5.25	3.85	3.55
30	11.00	10.65	9.40	5.35	4.00	3.70
40	10.80	10.55	9.10	5.10	3.80	3.45
50	10.55	10.25	9.00	5.10	3.90	3.45
60	10.20	10.00	8.65	4.95	3.80	3.60
70	10.00	9.70	8.35	4.85	3.70	3.55
80	9.70	9.50	8.25	4.85	3.85	3.55
90	9.55	9.25	7.90	4.60	3.75	3.45
100	9.10	8.85	7.65	4.55	3.55	3.25
110	8.90	8.60	7.35	4.35	3.40	3.20
120	8.50	8.25	7.15	4.20	3.30	3.20
130	8.05	7.80	6.70	3.80	3.25	3.05
140	7.75	7.50	6.05	3.70	3.10	3.05
150	7.50	7.25	6.30	3.65	3.15	3.05
160	7.20	7.00	6.90	3.55	3.15	3.00
170	7.05	6.80	5.80	3.40	3.35	3.05
180	7.30	7.05	6.00	3.72	3.35	2.95
190	6.55	6.35	5.35	3.60	3.30	3.05
200	7.15	6.95	5.95	3.75	3.20	2.95
210	7.25	7.05	6.05	3.80	3.25	3.05
220	7.55	7.30	6.35	3.90	3.35	3.25
230	8.05	7.80	6.75	4.10	3.45	3.35
240	8.30	8.05	7.00	4.25	3.60	3.40
250	8.55	8.35	7.25	4.50	3.75	3.45
260	8.85	8.65	7.45	4.50	3.65	3.55
270	9.10	8.95	7.80	4.70	3.80	3.55
280	9.35	9.20	7.95	4.80	3.95	3.50
290	9.50	9.35	8.05	4.85	3.85	3.45
300	9.90	9.60	8.30	4.85	4.00	3.55
310	10.25	9.85	8.50	4.95	4.10	4.70
320	10.40	10.30	8.90	5.10	4.15	4.45
330	10.55	10.50	8.95	5.25	4.10	3.50
340	10.65	10.45	9.10	5.30	4.15	3.55
350	10.85	10.50	9.20	5.30	4.15	3.55
360	10.90	10.65	9.30	5.25	4.20	3.55

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TABLE V

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q, IN INCHES OF WATER

$$\frac{x}{D} = 12$$

Distance from Nozzle Center inches

Degrees	0.0	0.1	0.2	0.3	0.5	0.7	0.9	1.1 to 2.5
10	8.20	8.05	7.95	6.95	5.80	4.65	4.05	3.60
20	8.20	8.10	7.90	6.95	5.80	4.65	4.00	3.60
30	8.30	8.15	7.90	7.00	5.95	4.65	4.05	3.65
40	8.11	7.95	7.70	6.85	5.75	4.50	4.00	3.60
50	7.85	7.70	7.70	6.65	5.65	4.50	3.90	3.60
60	7.90	7.80	7.50	6.60	5.60	4.55	4.05	3.70
70	7.60	7.40	7.20	6.35	5.55	4.35	3.95	3.60
80	7.60	7.35	7.50	6.15	5.55	5.00	4.00	3.65
90	7.20	7.00	6.72	6.09	5.22	4.30	3.90	3.50
100	7.00	6.80	6.55	5.80	5.15	4.06	3.68	3.40
110	6.75	6.50	6.40	5.65	4.90	4.05	3.60	3.30
120	6.50	6.30	6.10	5.50	4.75	3.90	3.53	3.30
130	6.35	6.10	5.90	5.35	4.60	3.75	3.50	3.20
140	6.10	5.85	5.85	5.12	4.41	3.70	3.44	3.20
150	5.90	5.75	5.40	5.00	4.32	3.52	3.30	3.00
160	5.66	5.00	5.15	4.85	4.25	3.50	3.25	3.00
170	5.31	5.10	4.75	4.51	3.96	3.40	3.10	2.90
180	5.60	5.40	5.07	4.75	4.20	3.50	3.25	3.00
190	5.40	5.20	4.90	4.60	4.10	4.10	3.20	2.95
200	5.50	5.25	5.00	4.69	4.20	3.53	3.25	2.90
210	5.50	5.25	5.15	4.80	4.30	3.40	3.23	3.00
220	5.80	5.68	5.35	5.00	4.40	3.71	3.30	3.10
230	6.10	5.90	5.70	5.15	4.55	3.85	3.50	3.20
240	6.27	6.02	5.88	5.25	4.60	3.90	3.59	3.30
250	6.70	6.40	6.20	5.60	4.90	4.11	3.70	3.45
260	6.85	6.65	6.35	5.75	5.10	4.20	3.80	3.55
270	7.00	6.85	6.65	5.95	5.20	4.30	3.90	3.60
280	7.15	6.95	6.75	6.00	5.35	4.40	3.90	3.60
290	7.30	7.10	6.95	6.15	5.40	4.45	3.91	3.60
300	7.50	7.30	7.05	6.30	5.45	4.40	3.90	3.50
310	7.75	7.50	7.30	6.40	5.60	4.40	3.85	3.50
320	7.73	7.60	7.34	6.50	5.55	4.40	3.90	3.50
330	8.00	7.65	7.50	6.70	5.70	4.35	3.95	3.55
340	8.15	7.95	7.70	6.70	5.70	4.50	3.95	3.60
350	8.13	7.95	7.70	6.80	5.85	4.60	4.00	3.55
360	8.25	8.05	7.90	6.90	5.95	4.55	4.02	3.60

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TABLE 7

WATER TEMPERATURE

TEMPERATURE OF WATER IN THE LAKE AT THE TIME OF THE

WATER

WATER TEMPERATURE

0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1	25.2	25.3	25.4	25.5	25.6	25.7	25.8	25.9	26.0	26.1	26.2	26.3	26.4	26.5	26.6	26.7	26.8	26.9	27.0	27.1	27.2	27.3	27.4	27.5	27.6	27.7	27.8	27.9	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5	30.6	30.7	30.8	30.9	31.0	31.1	31.2	31.3	31.4	31.5	31.6	31.7	31.8	31.9	32.0	32.1	32.2	32.3	32.4	32.5	32.6	32.7	32.8	32.9	33.0	33.1	33.2	33.3	33.4	33.5	33.6	33.7	33.8	33.9	34.0	34.1	34.2	34.3	34.4	34.5	34.6	34.7	34.8	34.9	35.0	35.1	35.2	35.3	35.4	35.5	35.6	35.7	35.8	35.9	36.0	36.1	36.2	36.3	36.4	36.5	36.6	36.7	36.8	36.9	37.0	37.1	37.2	37.3	37.4	37.5	37.6	37.7	37.8	37.9	38.0	38.1	38.2	38.3	38.4	38.5	38.6	38.7	38.8	38.9	39.0	39.1	39.2	39.3	39.4	39.5	39.6	39.7	39.8	39.9	40.0	40.1	40.2	40.3	40.4	40.5	40.6	40.7	40.8	40.9	41.0	41.1	41.2	41.3	41.4	41.5	41.6	41.7	41.8	41.9	42.0	42.1	42.2	42.3	42.4	42.5	42.6	42.7	42.8	42.9	43.0	43.1	43.2	43.3	43.4	43.5	43.6	43.7	43.8	43.9	44.0	44.1	44.2	44.3	44.4	44.5	44.6	44.7	44.8	44.9	45.0	45.1	45.2	45.3	45.4	45.5	45.6	45.7	45.8	45.9	46.0	46.1	46.2	46.3	46.4	46.5	46.6	46.7	46.8	46.9	47.0	47.1	47.2	47.3	47.4	47.5	47.6	47.7	47.8	47.9	48.0	48.1	48.2	48.3	48.4	48.5	48.6	48.7	48.8	48.9	49.0	49.1	49.2	49.3	49.4	49.5	49.6	49.7	49.8	49.9	50.0	50.1	50.2	50.3	50.4	50.5	50.6	50.7	50.8	50.9	51.0	51.1	51.2	51.3	51.4	51.5	51.6	51.7	51.8	51.9	52.0	52.1	52.2	52.3	52.4	52.5	52.6	52.7	52.8	52.9	53.0	53.1	53.2	53.3	53.4	53.5	53.6	53.7	53.8	53.9	54.0	54.1	54.2	54.3	54.4	54.5	54.6	54.7	54.8	54.9	55.0	55.1	55.2	55.3	55.4	55.5	55.6	55.7	55.8	55.9	56.0	56.1	56.2	56.3	56.4	56.5	56.6	56.7	56.8	56.9	57.0	57.1	57.2	57.3	57.4	57.5	57.6	57.7	57.8	57.9	58.0	58.1	58.2	58.3	58.4	58.5	58.6	58.7	58.8	58.9	59.0	59.1	59.2	59.3	59.4	59.5	59.6	59.7	59.8	59.9	60.0	60.1	60.2	60.3	60.4	60.5	60.6	60.7	60.8	60.9	61.0	61.1	61.2	61.3	61.4	61.5	61.6	61.7	61.8	61.9	62.0	62.1	62.2	62.3	62.4	62.5	62.6	62.7	62.8	62.9	63.0	63.1	63.2	63.3	63.4	63.5	63.6	63.7	63.8	63.9	64.0	64.1	64.2	64.3	64.4	64.5	64.6	64.7	64.8	64.9	65.0	65.1	65.2	65.3	65.4	65.5	65.6	65.7	65.8	65.9	66.0	66.1	66.2	66.3	66.4	66.5	66.6	66.7	66.8	66.9	67.0	67.1	67.2	67.3	67.4	67.5	67.6	67.7	67.8	67.9	68.0	68.1	68.2	68.3	68.4	68.5	68.6	68.7	68.8	68.9	69.0	69.1	69.2	69.3	69.4	69.5	69.6	69.7	69.8	69.9	70.0	70.1	70.2	70.3	70.4	70.5	70.6	70.7	70.8	70.9	71.0	71.1	71.2	71.3	71.4	71.5	71.6	71.7	71.8	71.9	72.0	72.1	72.2	72.3	72.4	72.5	72.6	72.7	72.8	72.9	73.0	73.1	73.2	73.3	73.4	73.5	73.6	73.7	73.8	73.9	74.0	74.1	74.2	74.3	74.4	74.5	74.6	74.7	74.8	74.9	75.0	75.1	75.2	75.3	75.4	75.5	75.6	75.7	75.8	75.9	76.0	76.1	76.2	76.3	76.4	76.5	76.6	76.7	76.8	76.9	77.0	77.1	77.2	77.3	77.4	77.5	77.6	77.7	77.8	77.9	78.0	78.1	78.2	78.3	78.4	78.5	78.6	78.7	78.8	78.9	79.0	79.1	79.2	79.3	79.4	79.5	79.6	79.7	79.8	79.9	80.0	80.1	80.2	80.3	80.4	80.5	80.6	80.7	80.8	80.9	81.0	81.1	81.2	81.3	81.4	81.5	81.6	81.7	81.8	81.9	82.0	82.1	82.2	82.3	82.4	82.5	82.6	82.7	82.8	82.9	83.0	83.1	83.2	83.3	83.4	83.5	83.6	83.7	83.8	83.9	84.0	84.1	84.2	84.3	84.4	84.5	84.6	84.7	84.8	84.9	85.0	85.1	85.2	85.3	85.4	85.5	85.6	85.7	85.8	85.9	86.0	86.1	86.2	86.3	86.4	86.5	86.6	86.7	86.8	86.9	87.0	87.1	87.2	87.3	87.4	87.5	87.6	87.7	87.8	87.9	88.0	88.1	88.2	88.3	88.4	88.5	88.6	88.7	88.8	88.9	89.0	89.1	89.2	89.3	89.4	89.5	89.6	89.7	89.8	89.9	90.0	90.1	90.2	90.3	90.4	90.5	90.6	90.7	90.8	90.9	91.0	91.1	91.2	91.3	91.4	91.5	91.6	91.7	91.8	91.9	92.0	92.1	92.2	92.3	92.4	92.5	92.6	92.7	92.8	92.9	93.0	93.1	93.2	93.3	93.4	93.5	93.6	93.7	93.8	93.9	94.0	94.1	94.2	94.3	94.4	94.5	94.6	94.7	94.8	94.9	95.0	95.1	95.2	95.3	95.4	95.5	95.6	95.7	95.8	95.9	96.0	96.1	96.2	96.3	96.4	96.5	96.6	96.7	96.8	96.9	97.0	97.1	97.2	97.3	97.4	97.5	97.6	97.7	97.8	97.9	98.0	98.1	98.2	98.3	98.4	98.5	98.6	98.7	98.8	98.9	99.0	99.1	99.2	99.3	99.4	99.5	99.6	99.7	99.8	99.9	100.0	100.1	100.2	100.3	100.4	100.5	100.6	100.7	100.8	100.9	101.0	101.1	101.2	101.3	101.4	101.5	101.6	101.7	101.8	101.9	102.0	102.1	102.2	102.3	102.4	102.5	102.6	102.7	102.8	102.9	103.0	103.1	103.2	103.3	103.4	103.5	103.6	103.7	103.8	103.9	104.0	104.1	104.2	104.3	104.4	104.5	104.6	104.7	104.8	104.9	105.0	105.1	105.2	105.3	105.4	105.5	105.6	105.7	105.8	105.9	106.0	106.1	106.2	106.3	106.4	106.5	106.6	106.7	106.8	106.9	107.0	107.1	107.2	107.3	107.4	107.5	107.6	107.7	107.8	107.9	108.0	108.1	108.2	108.3	108.4	108.5	108.6	108.7	108.8	108.9	109.0	109.1	109.2	109.3	109.4	109.5	109.6	109.7	109.8	109.9	110.0	110.1	110.2	110.3	110.4	110.5	110.6	110.7	110.8	110.9	111.0	111.1	111.2	111.3	111.4	111.5	111.6	111.7	111.8	111.9	112.0	112.1	112.2	112.3	112.4	112.5	112.6	112.7	112.8	112.9	113.0	113.1	113.2	113.3	113.4	113.5	113.6	113.7	113.8	113.9	114.0	114.1	114.2	114.3	114.4	114.5	114.6	114.7	114.8	114.9	115.0	115.1	115.2	115.3	115.4	115.5	115.6	115.7	115.8	115.9	116.0	116.1	116.2	116.3	116.4	116.5	116.6	116.7	116.8	116.9	117.0	117.1	117.2	117.3	117.4	117.5	117.6	117.7	117.8	117.9	118.0	118.1	118.2	118.3	118.4	118.5	118.6	118.7	118.8	118.9	119.0	119.1	119.2	119.3	119.4	119.5	119.6	119.7	119.8	119.9	120.0	120.1	120.2	120.3	120.4	120.5	120.6	120.7	120.8	120.9	121.0	121.1	121.2	121.3	121.4	121.5	121.6	121.7	121.8	121.9	122.0	122.1	122.2	122.3	122.4	122.5	122.6	122.7	122.8	122.9	123.0	123.1	123.2	123.3	123.4	123.5	123.6	123.7	123.8	123.9	124.0	124.1	124.2	124.3	124.4	124.5	124.6	124.7	124.8	124.9	125.0	125.1	125.2	125.3	125.4	125.5	125.6	125.7	125.8	125.9	126.0	126.1	126.2	126.3	126.4	126.5	126.6	126.7	126.8	126.9	127.0	127.1	127.2	127.3	127.4	127.5	127.6	127.7	127.8	127.9	128.0	128.1	128.2	128.3	128.4	128.5	128.6	128.7	128.8	128.9	129.0	129.1	129.2	129.3	129.4	129.5	129.6	129.7	129.8	129.9	130.0	130.1	130.2	130.3	130.4	130.5	130.6	130.7	130.8	130.9	131.0	131.1	131.2	131.3	131.4	131.5	131.6	131.7	131.8	131.9	
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TABLE VI

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q , IN INCHES OF WATER

$$\frac{x}{D} = 21$$

Distance from Hozzle Center, inches

Degrees	0.0	0.8	1.2	1.3	1.5 to 2.5
10	5.02	4.50	4.00	3.80	3.60
20	5.18	4.65	4.15	3.95	3.65
30	5.23	4.70	4.20	4.00	3.70
40	5.02	4.65	4.15	3.95	3.50
50	4.95	4.50	4.10	3.90	3.50
60	5.00	4.50	4.10	3.90	3.70
70	4.85	4.40	4.00	3.80	3.65
80	4.80	4.25	3.85	3.75	3.75
90	4.70	4.15	3.85	3.75	3.65
100	4.47	4.05	3.75	3.75	3.45
110	4.30	3.95	3.65	3.55	3.50
120	4.25	3.85	3.55	3.45	3.40
130	4.20	3.85	3.55	3.45	3.35
140	4.15	3.75	3.45	3.35	3.30
150	4.1	3.75	3.45	3.35	3.30
160	4.0	3.60	3.40	3.30	3.20
170	3.95	3.60	3.30	3.10	3.10
180	4.05	3.50	3.40	3.30	3.30
190	3.95	3.40	3.30	3.20	3.20
200	3.85	3.60	3.40	3.30	3.10
210	4.05	3.40	3.30	3.20	3.20
220	4.15	3.40	3.40	3.30	3.50
230	4.2	3.50	3.30	3.20	3.20
240	4.05	3.75	3.50	3.40	3.40
250	4.20	3.75	3.60	3.50	3.50
260	4.40	3.75	3.75	3.65	3.65
270	4.65	4.00	3.75	3.65	3.65
280	4.65	4.10	3.80	3.70	3.50
290	4.75	4.30	4.00	3.80	3.65
300	4.80	4.40	4.00	3.80	3.50
310	4.95	4.55	4.05	3.85	3.70
320	4.90	4.50	4.10	3.90	3.50
330	4.95	4.45	4.05	3.85	3.65
340	5.08	4.55	4.15	3.95	3.65
350	5.18	4.70	4.20	4.00	3.70
360	5.18	4.70	4.20	4.00	3.50

TABLE VII

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q, IN INCHES OF WATER

$$\frac{x}{D} = 24\frac{1}{2}$$

Distance from Nozzle Center, inches

	0.0					
Degrees	0.2	0.4	0.8	1.0	1.4	1.6 to 2.5
10	4.75	4.50	4.30	3.95	3.70	3.65
20	4.75	4.60	4.20	4.05	3.75	3.65
30	4.70	4.50	4.20	3.95	3.75	3.55
40	4.60	4.35	4.00	3.85	3.70	3.45
50	4.70	4.50	4.10	4.05	3.85	3.60
60	4.80	4.60	4.20	4.05	3.90	3.75
70	4.80	4.60	4.20	4.20	4.00	3.75
80	4.75	4.55	4.20	4.10	3.90	3.75
90	4.50	4.25	4.05	4.05	3.85	3.65
100	4.35	4.20	3.85	3.85	3.65	3.45
110	4.25	4.20	3.90	3.90	3.75	3.55
120	4.15	4.15	3.75	3.75	3.55	3.35
130	4.15	4.10	3.75	3.65	3.55	3.40
140	4.10	4.05	3.70	3.65	3.45	3.25
150	4.00	4.00	3.65	3.65	3.45	3.25
160	3.9	3.95	3.45	3.65	3.40	3.25
170	3.90	3.85	3.55	3.50	3.20	3.20
180	4.00	3.90	3.40	3.50	3.40	3.15
190	3.90	3.85	3.30	3.50	3.40	3.15
200	3.80	3.70	3.30	3.50	3.40	3.15
210	4.00	3.80	3.55	3.50	3.50	3.15
220	4.10	3.95	3.75	3.70	3.60	3.25
230	4.15	3.85	3.55	3.55	3.45	3.20
240	4.0	3.95	3.65	3.65	3.55	3.25
250	4.15	4.20	3.85	3.80	3.65	3.40
260	4.30	4.20	3.95	3.90	3.75	3.50
270	4.50	4.25	3.95	3.90	3.75	3.50
280	4.40	4.20	3.85	3.80	3.70	3.45
290	4.55	4.25	4.00	3.95	3.80	3.55
300	4.05	3.85	4.05	4.00	3.90	3.60
310	4.60	4.35	4.20	4.05	3.90	3.65
320	4.65	4.40	4.05	4.00	3.95	3.60
330	4.50	4.25	4.10	4.00	3.80	3.60
340	4.65	4.40	4.05	4.00	3.80	3.60
350	4.70	4.50	4.20	4.05	3.85	3.75
360	4.75	4.55	4.25	4.15	3.75	3.75

TABLE VIII

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE , q, IN INCHES OF WATER

$$\frac{x}{D} = 27\frac{1}{2}$$

Distance from Nozzle Center, inches

Degree	0.0				
	0.2	0.9	1.5	1.7 to 2.5	0.4
10	4.25	3.85	3.80	3.70	
20	4.40	4.00	3.85	3.75	
30	4.25	3.85	3.75	3.60	
40	4.15	3.75	3.65	3.55	
50	4.25	3.85	3.75	3.70	
60	4.40	4.00	3.90	3.80	
70	4.40	4.00	3.90	3.85	
80	4.30	4.00	3.90	3.80	
90	4.05	3.75	3.65	3.75	
100	3.95	3.75	3.65	3.55	
110	3.95	3.75	3.65	3.50	
120	3.85	3.75	3.65	3.40	
130	3.85	3.70	3.60	3.40	
140	3.75	3.65	3.55	3.30	
150	3.70	3.65	3.55	3.30	
160	3.70	3.60	3.50	3.30	
170	3.70	3.60	3.50	3.20	
180	3.60	3.50	3.40	3.20	
190	3.50	3.40	3.30	3.20	
200	3.35	3.25	3.15	3.20	
210	3.55	3.45	3.35	3.20	
220	3.75	3.65	3.55	3.40	
230	3.70	3.60	3.50	3.25	
240	3.75	3.60	3.50	3.30	
250	3.95	3.75	3.65	3.50	
260	4.00	3.80	3.70	3.60	
270	4.05	3.85	3.75	3.60	
280	4.00	3.80	3.70	3.50	
290	4.05	3.85	3.75	3.60	
300	3.60	3.40	3.30	3.70	
310	4.20	3.90	3.80	3.75	
320	4.20	3.90	3.80	3.70	
330	4.10	3.80	3.70	3.70	
340	4.20	3.80	3.70	3.70	
350	4.30	3.90	3.80	3.75	
360	4.30	3.90	3.80	3.75	

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TABLE IX

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q , IN INCHES OF WATER

$$\frac{x}{D} = 30$$

Distance from Nozzle Center, inches

Degree	0.0				
	0.2	0.7	1.3	1.8 to 2.5	
	0.4				
10	4.25	4.05	3.85	3.70	
20	4.20	4.00	3.80	3.75	
30	4.20	4.00	3.80	3.60	
40	4.00	3.80	3.70	3.55	
50	4.05	3.85	3.75	3.70	
60	4.15	3.95	3.85	3.80	
70	4.20	4.00	3.90	3.85	
80	4.20	4.00	3.90	3.80	
90	4.05	3.85	3.75	3.75	
100	3.85	3.75	3.65	3.55	
110	3.90	3.80	3.70	3.55	
120	3.75	3.65	3.55	3.40	
130	3.75	3.65	3.55	3.40	
140	3.70	3.60	3.50	3.30	
150	3.60	3.60	3.50	3.30	
160	3.50	3.50	3.45	3.30	
170	3.55	3.50	3.40	3.20	
180	3.40	3.35	3.30	3.20	
190	3.30	3.25	3.20	3.20	
200	3.30	3.25	3.20	3.20	
210	3.55	3.45	3.35	3.20	
220	3.75	3.65	3.55	3.40	
230	3.55	3.45	3.35	3.25	
240	3.60	3.50	3.40	3.30	
250	3.85	3.70	3.60	3.50	
260	3.95	3.85	3.75	3.60	
270	3.95	3.85	3.75	3.60	
280	3.85	3.75	3.70	3.50	
290	4.00	3.90	3.80	3.60	
300	4.05	3.95	3.75	3.70	
310	4.15	3.95	3.75	3.75	
320	4.05	3.90	3.70	3.70	
330	4.10	3.90	3.75	3.70	
340	4.05	3.95	3.75	3.70	
350	4.20	4.00	3.80	3.75	
360	4.25	4.05	3.80	3.75	

TABLE X

PULSATING FLOW

CYCLE OF DYNAMIC PRESSURE, q , IN INCHES OF WATER

$$\frac{x}{D} = 39$$

[illegible]

STATION ON HIGHWAY 10, 1/2 MILE N. OF

$$U = \frac{1}{10}$$

1930

10	8.70
20	8.75
30	8.80
40	8.85
50	8.90
60	8.95
70	9.00
80	9.05
90	9.10
100	9.15
110	9.20
120	9.25
130	9.30
140	9.35
150	9.40
160	9.45
170	9.50
180	9.55
190	9.60
200	9.65
210	9.70
220	9.75
230	9.80
240	9.85
250	9.90
260	9.95
270	10.00
280	10.05
290	10.10
300	10.15
310	10.20
320	10.25
330	10.30
340	10.35
350	10.40
360	10.45
370	10.50
380	10.55
390	10.60
400	10.65
410	10.70
420	10.75
430	10.80
440	10.85
450	10.90
460	10.95
470	11.00
480	11.05
490	11.10
500	11.15

TABLE XI

MAXIMUM DYNAMIC PRESSURE PROFILE

q, INCHES OF WATER

Pulsating Jet

$\frac{y}{D}$	$\frac{x}{D}=0$	3	5	9	12	21	24.5	27.5	30	39
0	15.8	15.45	14.25	11.25	8.3	5.2	4.75	4.4	4.2	3.75
.1	15.3		13.85	10.75	8.1		4.75	4.4		3.75
.2	15.	14.75	12.7	9.25	7.9			4.4	4.2	3.75
.3	14.1	13.40	10.0		6.95					3.75
.4	11.95	10.9	7.5				4.6	4.4	4.2	3.75
.5	9.75	7.05	5.05	5.25	5.8					3.75
.6		4.05	3.60							3.75
.7		3.5		3.85	4.65				4.0	3.75
.8		3.5	3.5			4.65	4.2			3.75
.9		3.5	3.5	3.55	4.0			4.0		3.75
1.0	3.4	3.5	3.5	3.55	3.75		4.05			3.75
1.1	3.4	3.5	3.5	3.55	3.6					3.75
1.2	3.4	3.5	3.5	3.55	3.6	4.15				3.75
1.3	3.4	3.5	3.5	3.55	3.6	3.95			3.8	3.75
1.4	3.4	3.5	3.5	3.55	3.6		3.75			3.75
1.5	3.4	3.5	3.5	3.55	3.6	3.65		3.8		3.75
1.6	3.4	3.5	3.5	3.55	3.6	3.65	3.65			3.75
1.7	3.4	3.5	3.5	3.55	3.6	3.65		3.75		3.75
1.8	3.4	3.5	3.5	3.55	3.6	3.65	3.65	3.75	3.75	3.75
2.5	3.4	3.5	3.5	3.55	3.6	3.65	3.65	3.75	3.75	3.75

TABLE XII

MINIMUM DYNAMIC PRESSURE PROFILE

q, INCHES OF WATER

Pulsating Jet

$\frac{y}{D}$	$\frac{x}{D} = 0$	3	5	9	12	21	24.5	27.5	30		
0	9.95	9.70	9.0	7.05	5.31	3.95	3.90	3.7	3.55		
0.1	9.4		8.6	6.8	5.1						
0.2	9.3	9.10	7.9	5.8	4.75			3.7			
0.3	8.6	8.20	6.1		4.51						
0.4	6.9	6.85	4.45		3.96		3.85	3.7			
0.5	5.4	4.6	3.23	3.4							
0.6		3.15									
0.7		3.00		3.15	3.4				3.5		
0.8		3.00	2.95			3.6	3.55				
0.9		3.00	2.95	3.05	3.1			3.6			
1.0	3.05	3.00	2.95	3.05			3.50				
1.1	3.05	3.00	2.95	3.05	2.9						
1.2	3.05	3.00	2.95	3.05	2.9	3.3					
1.3	3.05	3.00	2.95	3.05	2.9	3.1			3.4		
1.4	3.05	3.00	2.95	3.05	2.9	3.1	3.2	3.5			
1.5	3.05	3.00	2.95	3.05	2.9	3.1	3.2				
1.6	3.05	3.00	2.95	3.05	2.9	3.1	3.2				
1.7	3.05	3.00	2.95	3.05	2.9	3.1	3.2	3.2			
1.8	3.05	3.00	2.95	3.05	2.9	3.1	3.2	3.2	3.2		
2.5	3.05	3.00	2.95	3.05	2.9	3.1	3.2	3.2	3.2		

00	2.74	3.74	4.74	5.74	6.74	7.74	8.74	9.74	10.74	11.74
00.0	7.5	00.0	00.0	11.0	20.7	0.0	00.0	00.0	0.0	0.0
				1.0	00.0	0.0			0.0	1.0
	7.5			00.0	0.0	0.0	00.0	0.0	0.0	0.0
				10.0		1.0	00.0	0.0	0.0	0.0
	7.0	00.0		00.0		00.0	00.0	0.0	0.0	0.0
					0.0	00.0	0.0	0.0	0.0	0.0
					0.0	00.0	0.0	0.0	0.0	0.0
0.0				0.0	00.0		00.0			0.0
		00.0	0.0			00.0	00.0			0.0
	0.0			1.0	00.0	00.0	00.0			0.0
		00.0			0.0	00.0	00.0	00.0	0.0	0.0
				0.0	0.0	00.0	00.0	00.0	0.0	0.0
				0.0	0.0	00.0	00.0	00.0	0.0	0.0
0.0				0.0	0.0	00.0	00.0	00.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	00.0	00.0	00.0	0.0	0.0
		0.0	0.0	0.0	0.0	00.0	00.0	00.0	0.0	0.0
		0.0	0.0	0.0	0.0	00.0	00.0	00.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	00.0	00.0	00.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	00.0	00.0	00.0	0.0	0.0

TABLE XIII

INTERMEDIATE DYNAMIC PRESSURE PROFILE

q, INCHES OF WATER

Pulsating Jet

$\frac{Y}{D}$	$\frac{x}{D}$	0	3	5	9	12	21	24.5	27.5	30	39
0	11.4	11.15	10.35	8.05	6.35	4.20	4.15	3.85	3.75	3.4	3.4
0.1	10.85		10.0	7.8	6.1						3.4
0.2	10.7	10.5	9.1	6.7	5.9		4.15				3.4
0.3	9.85	9.55	7.05		5.35						3.4
0.4	8.10	7.8	5.20				4.10	3.85	3.75	3.4	3.4
0.5	6.50	5.10	4.02	3.8	4.60						3.4
0.6	3.25	3.25									3.4
0.7	3.25	3.20		3.4	3.75					3.65	3.4
0.8	3.25	3.20	3.20			3.85	3.75				3.4
0.9	3.25	3.20	3.20	3.25	3.50			3.7			3.4
1.0	3.25	3.20	3.20	3.25			3.65				3.4
1.1	3.25	3.20	3.20	3.25	3.20						3.4
1.2	3.25	3.20	3.20	3.25	3.20	3.55					3.4
1.3	3.25	3.20	3.20	3.25	3.20	3.45				3.55	3.4
1.4	3.25	3.20	3.20	3.25	3.20		3.55				3.4
1.5	3.25	3.20	3.20	3.25	3.20	3.35		3.6			3.4
1.6	3.25	3.20	3.20	3.25	3.20	3.35	3.4				3.4
1.7	3.25	3.20	3.20	3.25	3.20	3.35	3.4	3.4			3.4
1.8	3.25	3.20	3.20	3.25	3.20	3.35	3.4	3.4	3.4	3.4	3.4

[illegible]

TABLE XIV

DYNAMIC PRESSURE PROFILE

Steady Flow - Intermediate Value

q, inches of water

$\frac{y}{D}$	$\frac{x}{D}$	0	3	5	9	12	16	21	24.5	27.5	30
0		11.4	10.7	10.3	7.6	5.9	4.3	3.4	3.2	2.95	2.9
0.1		11.3	10.6	9.8	7.3	5.9	4.2	3.4	3.15	2.95	2.9
0.2		10.7	10.2	8.5		5.4	4.2	3.35	3.10	2.9	2.9
0.3		9.4	9.1	6.2	6.2	4.6	4.1	3.2	3.1	2.9	2.85
0.4		7.1	6.1	4.6	4.8	4.2	3.9	3.1	3.0	2.9	2.7
0.5		5.9	3.7	2.9	3.9	3.5	3.4	3.0	2.95	2.85	2.65
0.6		2.3	2.5	2.4	3.4	3.0	3.2	2.9	2.90	2.8	2.6
0.7		2.2	2.3	2.3	2.9		3.0		2.85	2.75	2.6
0.8		2.2	2.3	2.3	2.6	2.7	2.9	2.7	2.8	2.7	2.6
0.9		2.3	2.3	2.3	2.5	2.6	2.7	2.7	2.7	2.7	2.6
1.0		2.3	2.3	2.3	2.4	2.5	2.6	2.6	2.6	2.6	2.6
1.1		2.3	2.3	2.3	2.4	2.4	2.6	2.55	2.55	2.6	2.5
1.2		2.3	2.3	2.3	2.4	2.4	2.5	2.5	2.45	2.55	2.45
1.3		2.3	2.3	2.3	2.4	2.4	2.5	2.4	2.4	2.5	2.45
1.4		2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.45	2.45
1.5		2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.45
1.6		2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.45
2.0		2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.45

Table 1

Time of counting
10 min

Linear plot, 10 min

No.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	$\frac{x}{d}$	
1.	11.	21.	31.	41.	51.						0	
2.	12.	22.	32.	42.	52.	10.	10.	20.	30.	40.	1	
	13.	23.	33.	43.	53.	11.	11.	21.	31.	41.	2	
				44.	54.	12.	12.	22.	32.	42.	3	
				45.	55.	13.	13.	23.	33.	43.	4	
					56.	14.	14.	24.	34.	44.	5	
						15.	15.	25.	35.	45.	6	
							16.	26.	36.	46.	7	
								27.	37.	47.	8	
									28.	38.	9	
										29.	10	
											11	
											12	
											13	
											14	
											15	
											16	
											17	
											18	
											19	
											20	

TABLE XVII

Lines of Constant $\frac{q-q_s}{q_0-q_s}$

Intermediate Value, Pulsating Flow

[illegible]

TABLE 1

$$\frac{1}{2} \left(\frac{1}{\alpha} + \frac{1}{\beta} \right) = \frac{1}{2} \left(\frac{1}{\alpha} + \frac{1}{\beta} \right)$$
 (continued on next page)

1	2	3	4	5	6	7	8	9	10	11	12	13
14	15	16	17	18	19	20	21	22	23	24	25	26
27	28	29	30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47	48	49	50	51	52
53	54	55	56	57	58	59	60	61	62	63	64	65
66	67	68	69	70	71	72	73	74	75	76	77	78
79	80	81	82	83	84	85	86	87	88	89	90	91
92	93	94	95	96	97	98	99	100	101	102	103	104
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144	145	146	147	148	149	150	151	152	153	154	155	156
157	158	159	160	161	162	163	164	165	166	167	168	169
170	171	172	173	174	175	176	177	178	179	180	181	182
183	184	185	186	187	188	189	190	191	192	193	194	195
196	197	198	199	200	201	202	203	204	205	206	207	208
209	210	211	212	213	214	215	216	217	218	219	220	221
222	223	224	225	226	227	228	229	230	231	232	233	234
235	236	237	238	239	240	241	242	243	244	245	246	247
248	249	250	251	252	253	254	255	256	257	258	259	260
261	262	263	264	265	266	267	268	269	270	271	272	273
274	275	276	277	278	279	280	281	282	283	284	285	286
287	288	289	290	291	292	293	294	295	296	297	298	299
300	301	302	303	304	305	306	307	308	309	310	311	312
313	314	315	316	317	318	319	320	321	322	323	324	325
326	327	328	329	330	331	332	333	334	335	336	337	338
339	340	341	342	343	344	345	346	347	348	349	350	351
352	353	354	355	356	357	358	359	360	361	362	363	364
365	366	367	368	369	370	371	372	373	374	375	376	377
378	379	380	381	382	383	384	385	386	387	388	389	390
391	392	393	394	395	396	397	398	399	400	401	402	403
404	405	406	407	408	409	410	411	412	413	414	415	416
417	418	419	420	421	422	423	424	425	426	427	428	429
430	431	432	433	434	435	436	437	438	439	440	441	442
443	444	445	446	447	448	449	450	451	452	453	454	455
456	457	458	459	460	461	462	463	464	465	466	467	468
469	470	471	472	473	474	475	476	477	478	479	480	481
482	483	484	485	486	487	488	489	490	491	492	493	494
495	496	497	498	499	500	501	502	503	504	505	506	507
508	509	510	511	512	513	514	515	516	517	518	519	520
521	522	523	524	525	526	527	528	529	530	531	532	533
534	535	536	537	538	539	540	541	542	543	544	545	546
547	548	549	550	551	552	553	554	555	556	557	558	559
560	561	562	563	564	565	566	567	568	569	570	571	572
573	574	575	576	577	578	579	580	581	582	583	584	585
586	587	588	589	590	591	592	593	594	595	596	597	598
599	600	601	602	603	604	605	606	607	608	609	610	611
612	613	614	615	616	617	618	619	620	621	622	623	624
625	626	627	628	629	630	631	632	633	634	635	636	637
638	639	640	641	642	643	644	645	646	647	648	649	650
651	652	653	654	655	656	657	658	659	660	661	662	663
664	665	666	667	668	669	670	671	672	673	674	675	676
677	678	679	680	681	682	683	684	685	686	687	688	689
690	691	692	693	694	695	696	697	698	699	700	701	702
703	704	705	706	707	708	709	710	711	712	713	714	715
716	717	718	719	720	721	722	723	724	725	726	727	728
729	730	731	732	733	734	735	736	737	738	739	740	741
742	743	744	745	746	747	748	749	750	751	752	753	754
755	756	757	758	759	760	761	762	763	764	765	766	767
768	769	770	771	772	773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788	789	790	791	792	793
794	795	796	797	798	799	800	801	802	803	804	805	806
807	808	809	810	811	812	813	814	815	816	817	818	819
820	821	822	823	824	825	826	827	828	829	830	831	832
833	834	835	836	837	838	839	840	841	842	843	844	845
846	847	848	849	850	851	852	853	854	855	856	857	858
859	860	861	862	863	864	865	866	867	868	869	870	871
872	873	874	875	876	877	878	879	880	881	882	883	884
885	886	887	888	889	890	891	892	893	894	895	896	897
898	899	900	901	902	903	904	905	906	907	908	909	910
911	912	913	914	915	916	917	918	919	920	921	922	923
924	925	926	927	928	929	930	931	932	933	934	935	936
937	938	939	940	941	942	943	944	945	946	947	948	949
950	951	952	953	954	955	956	957	958	959	960	961	962
963	964	965	966	967	968	969	970	971	972	973	974	975
976	977	978	979	980	981	982	983	984	985	986	987	988
989	990	991	992	993	994	995	996	997	998	999	1000	1001

TABLE XIX

Lines of Constant $\frac{q-q_s}{q_o-q_s}$

Maximum Value, Steady Flow

[illegible]

TABLE XX

CENTERLINE VALUES OF VELOCITY

(a) Steady Flow, intermediate values

$\frac{x}{D}$	$q-q_s$	q_0-q_s	$\frac{q_s}{q_0-q_s}$	$\frac{u-u_s}{u_0-u_s}$
0	9.0	9.0	1.0	1.0
3	8.3	9.0	.925	.963
5	7.9	9.0	.880	.940
9	5.2	9.0	.580	.762
12	3.5	9.0	.390	.625
21	1.0	9.0	.116	.340
24.5	0.8	9.0	.089	.298
27.5	0.55	9.0	.061	.247
30	0.50	9.0	.055	.234

(b) Pulsed Flow, intermediate values

0	8.05	8.05	1.0	1.0
3	7.80	8.05	.970	.985
5	7.00	8.05	.870	.935
9	4.70	8.05	.585	.765
12	3.00	8.05	.370	.610
21	0.85	8.05	.105	.324
24.5	0.80	8.05	.099	.310
27.5	0.50	8.05	.062	.249
30	0.40	8.05	.050	.224

TABLE

EXPOSURE OF CRYSTAL CALCULATED

CALCULATED EXPOSURE (100% CRISTAL) (a)

$\frac{d_{100}}{d_{hkl}}$	$\frac{d}{d_{hkl}}$	d_{100}^2	d^2	$\frac{d}{d_{100}}$
0.1	0.1	0.1	0.1	0
100.	100.	100.	100.	1
0.5.	0.5.	0.25	0.25	0.5
200.	400.	0.5	0.5	0.5
300.	900.	0.75	0.75	0.75
400.	1600.	1.0	1.0	1.0
500.	2500.	1.25	1.25	1.25
600.	3600.	1.5	1.5	1.5
700.	4900.	1.75	1.75	1.75
800.	6400.	2.0	2.0	2.0

CALCULATED EXPOSURE (100% CRISTAL) (b)

0.1	0.1	0.1	0.1	0
100.	100.	100.	100.	1
0.5.	0.5.	0.25	0.25	0.5
200.	400.	0.5	0.5	0.5
300.	900.	0.75	0.75	0.75
400.	1600.	1.0	1.0	1.0
500.	2500.	1.25	1.25	1.25
600.	3600.	1.5	1.5	1.5
700.	4900.	1.75	1.75	1.75
800.	6400.	2.0	2.0	2.0

TABLE XXI

NORMALIZED VELOCITY PROFILES

$$\frac{x}{D} = 12$$

(a) Steady Flow, Intermediate Value: $\frac{r_m}{r_o} = 0.49$, $r_o = 1.1$

$\frac{y}{D}$	q	$q - q_s$	$\frac{q - q_s}{q_o - q_s}$	$\frac{u - u_s}{u_o - u_s}$	$\frac{r}{r_m}$
0	5.9	3.5	1.0	1.0	0
0.1	5.9	3.5	1.0	1.0	0.184
0.2	5.4	3.0	0.855	0.925	0.37
0.3	4.6	2.2	0.63	0.795	0.55
0.4	4.2	1.8	0.515	0.718	0.73
0.5	3.5	1.1	0.315	0.56	0.92
0.6	3.0	0.6	0.171	0.413	1.13
0.7					
0.8	2.7	0.3	0.086	0.293	1.49
0.9	2.6	0.2	0.057	0.239	1.67
1.0	2.5	0.1	0.0285	0.169	1.86
1.1	2.4	0	0		2.04

(b) Pulsed Flow: $\frac{r_m}{r_o} = 0.575$, $r_o = 1.1$

$\frac{y}{D}$	q	$q - q_s$	$\frac{q - q_s}{q_o - q_s}$	$\frac{u - u_s}{u_o - u_s}$	$\frac{r}{r_m}$
0	6.35	3.15	1	1	0
0.1	6.10	2.90	0.923	0.96	0.159
0.2	5.9	2.7	0.855	0.925	0.317
0.3	5.35	2.15	0.683	0.815	0.475
0.5	4.6	1.4	0.445	0.666	0.790
0.7	3.75	0.55	0.175	0.418	1.10
0.9	3.50	0.30	0.095	0.308	1.42
1.1	3.20	0	0	0	1.74

TABLE III

RELATIVE VELOCITY COEFFICIENTS

$$R = \frac{v}{c}$$

(a) Steady flow, intermediate values: $\frac{v}{c} = 0.5$ to 0.9

$\frac{v}{c}$	$\frac{v}{c}$	$\frac{v}{c}$	$\frac{v}{c}$	$\frac{v}{c}$	$\frac{v}{c}$
0	0.1	0.1	0.2	0.3	0
0.1	0.2	0.2	0.3	0.4	0.1
0.2	0.3	0.3	0.4	0.5	0.2
0.3	0.4	0.4	0.5	0.6	0.3
0.4	0.5	0.5	0.6	0.7	0.4
0.5	0.6	0.6	0.7	0.8	0.5
0.6	0.7	0.7	0.8	0.9	0.6
0.7	0.8	0.8	0.9	1.0	0.7
0.8	0.9	0.9	1.0	1.1	0.8
0.9	1.0	1.0	1.1	1.2	0.9
1.0	1.1	1.1	1.2	1.3	1.0
1.1	1.2	1.2	1.3	1.4	1.1
1.2	1.3	1.3	1.4	1.5	1.2
1.3	1.4	1.4	1.5	1.6	1.3
1.4	1.5	1.5	1.6	1.7	1.4
1.5	1.6	1.6	1.7	1.8	1.5
1.6	1.7	1.7	1.8	1.9	1.6
1.7	1.8	1.8	1.9	2.0	1.7
1.8	1.9	1.9	2.0	2.1	1.8
1.9	2.0	2.0	2.1	2.2	1.9
2.0	2.1	2.1	2.2	2.3	2.0
2.1	2.2	2.2	2.3	2.4	2.1
2.2	2.3	2.3	2.4	2.5	2.2
2.3	2.4	2.4	2.5	2.6	2.3
2.4	2.5	2.5	2.6	2.7	2.4
2.5	2.6	2.6	2.7	2.8	2.5
2.6	2.7	2.7	2.8	2.9	2.6
2.7	2.8	2.8	2.9	3.0	2.7
2.8	2.9	2.9	3.0	3.1	2.8
2.9	3.0	3.0	3.1	3.2	2.9
3.0	3.1	3.1	3.2	3.3	3.0
3.1	3.2	3.2	3.3	3.4	3.1
3.2	3.3	3.3	3.4	3.5	3.2
3.3	3.4	3.4	3.5	3.6	3.3
3.4	3.5	3.5	3.6	3.7	3.4
3.5	3.6	3.6	3.7	3.8	3.5
3.6	3.7	3.7	3.8	3.9	3.6
3.7	3.8	3.8	3.9	4.0	3.7
3.8	3.9	3.9	4.0	4.1	3.8
3.9	4.0	4.0	4.1	4.2	3.9
4.0	4.1	4.1	4.2	4.3	4.0
4.1	4.2	4.2	4.3	4.4	4.1
4.2	4.3	4.3	4.4	4.5	4.2
4.3	4.4	4.4	4.5	4.6	4.3
4.4	4.5	4.5	4.6	4.7	4.4
4.5	4.6	4.6	4.7	4.8	4.5
4.6	4.7	4.7	4.8	4.9	4.6
4.7	4.8	4.8	4.9	5.0	4.7
4.8	4.9	4.9	5.0	5.1	4.8
4.9	5.0	5.0	5.1	5.2	4.9
5.0	5.1	5.1	5.2	5.3	5.0
5.1	5.2	5.2	5.3	5.4	5.1
5.2	5.3	5.3	5.4	5.5	5.2
5.3	5.4	5.4	5.5	5.6	5.3
5.4	5.5	5.5	5.6	5.7	5.4
5.5	5.6	5.6	5.7	5.8	5.5
5.6	5.7	5.7	5.8	5.9	5.6
5.7	5.8	5.8	5.9	6.0	5.7
5.8	5.9	5.9	6.0	6.1	5.8
5.9	6.0	6.0	6.1	6.2	5.9
6.0	6.1	6.1	6.2	6.3	6.0
6.1	6.2	6.2	6.3	6.4	6.1
6.2	6.3	6.3	6.4	6.5	6.2
6.3	6.4	6.4	6.5	6.6	6.3
6.4	6.5	6.5	6.6	6.7	6.4
6.5	6.6	6.6	6.7	6.8	6.5
6.6	6.7	6.7	6.8	6.9	6.6
6.7	6.8	6.8	6.9	7.0	6.7
6.8	6.9	6.9	7.0	7.1	6.8
6.9	7.0	7.0	7.1	7.2	6.9
7.0	7.1	7.1	7.2	7.3	7.0
7.1	7.2	7.2	7.3	7.4	7.1
7.2	7.3	7.3	7.4	7.5	7.2
7.3	7.4	7.4	7.5	7.6	7.3
7.4	7.5	7.5	7.6	7.7	7.4
7.5	7.6	7.6	7.7	7.8	7.5
7.6	7.7	7.7	7.8	7.9	7.6
7.7	7.8	7.8	7.9	8.0	7.7
7.8	7.9	7.9	8.0	8.1	7.8
7.9	8.0	8.0	8.1	8.2	7.9
8.0	8.1	8.1	8.2	8.3	8.0
8.1	8.2	8.2	8.3	8.4	8.1
8.2	8.3	8.3	8.4	8.5	8.2
8.3	8.4	8.4	8.5	8.6	8.3
8.4	8.5	8.5	8.6	8.7	8.4
8.5	8.6	8.6	8.7	8.8	8.5
8.6	8.7	8.7	8.8	8.9	8.6
8.7	8.8	8.8	8.9	9.0	8.7
8.8	8.9	8.9	9.0	9.1	8.8
8.9	9.0	9.0	9.1	9.2	8.9
9.0	9.1	9.1	9.2	9.3	9.0
9.1	9.2	9.2	9.3	9.4	9.1
9.2	9.3	9.3	9.4	9.5	9.2
9.3	9.4	9.4	9.5	9.6	9.3
9.4	9.5	9.5	9.6	9.7	9.4
9.5	9.6	9.6	9.7	9.8	9.5
9.6	9.7	9.7	9.8	9.9	9.6
9.7	9.8	9.8	9.9	10.0	9.7
9.8	9.9	9.9	10.0	10.1	9.8
9.9	10.0	10.0	10.1	10.2	9.9
10.0	10.1	10.1	10.2	10.3	10.0
10.1	10.2	10.2	10.3	10.4	10.1
10.2	10.3	10.3	10.4	10.5	10.2
10.3	10.4	10.4	10.5	10.6	10.3
10.4	10.5	10.5	10.6	10.7	10.4
10.5	10.6	10.6	10.7	10.8	10.5
10.6	10.7	10.7	10.8	10.9	10.6
10.7	10.8	10.8	10.9	11.0	10.7
10.8	10.9	10.9	11.0	11.1	10.8
10.9	11.0	11.0	11.1	11.2	10.9
11.0	11.1	11.1	11.2	11.3	11.0
11.1	11.2	11.2	11.3	11.4	11.1
11.2	11.3	11.3	11.4	11.5	11.2
11.3	11.4	11.4	11.5	11.6	11.3
11.4	11.5	11.5	11.6	11.7	11.4
11.5	11.6	11.6	11.7	11.8	11.5
11.6	11.7	11.7	11.8	11.9	11.6
11.7	11.8	11.8	11.9	12.0	11.7
11.8	11.9	11.9	12.0	12.1	11.8
11.9	12.0	12.0	12.1	12.2	11.9
12.0	12.1	12.1	12.2	12.3	12.0
12.1	12.2	12.2	12.3	12.4	12.1
12.2	12.3	12.3	12.4	12.5	12.2
12.3	12.4	12.4	12.5	12.6	12.3
12.4	12.5	12.5	12.6	12.7	12.4
12.5	12.6	12.6	12.7	12.8	12.5
12.6	12.7	12.7	12.8	12.9	12.6
12.7	12.8	12.8	12.9	13.0	12.7
12.8	12.9	12.9	13.0	13.1	12.8
12.9	13.0	13.0	13.1	13.2	12.9
13.0	13.1	13.1	13.2	13.3	13.0
13.1	13.2	13.2	13.3	13.4	13.1
13.2	13.3	13.3	13.4	13.5	13.2
13.3	13.4	13.4	13.5	13.6	13.3
13.4	13.5	13.5	13.6	13.7	13.4
13.5	13.6	13.6	13.7	13.8	13.5
13.6	13.7	13.7	13.8	13.9	13.6
13.7	13.8	13.8	13.9	14.0	13.7
13.8	13.9	13.9	14.0	14.1	13.8
13.9	14.0	14.0	14.1	14.2	13.9
14.0	14.1	14.1	14.2	14.3	14.0
14.1	14.2	14.2	14.3	14.4	14.1
14.2	14.3	14.3	14.4	14.5	14.2
14.3	14.4	14.4	14.5	14.6	14.3
14.4	14.5	14.5	14.6	14.7	14.4
14.5	14.6	14.6	14.7	14.8	14.5
14.6	14.7	14.7	14.8	14.9	14.6
14.7	14.8	14.8	14.9	15.0	14.7
14.8	14.9	14.9	15.0	15.1	14.8
14.9	15.0	15.0	15.1	15.2	14.9
15.0	15.1	15.1	15.2	15.3	15.0
15.1	15.2	15.2	15.3	15.4	15.1
15.2	15.3	15.3	15.4	15.5	15.2
15.3	15.4	15.4	15.5	15.6	15.3
15.4	15.5	15.5	15.6	15.7	15.4
15.5	15.6	15.6	15.7	15.8	15.5
15.6	15.7	15.7	15.8	15.9	15.6
15.7	15.8	15.8	15.9	16.0	15.7
15.8	15.9	15.9	16.0	16.1	15.8
15.9	16.0	16.0	16.1	16.2	15.9
16.0	16.1	16.1	16.2	16.3	16.0
16.1	16.2	16.2	16.3	16.4	16.1
16.2	16.3	16.3	16.4	16.5	16.2
16.3	16.4	16.4	16.5	16.6	16.3
16.4	16.5	16.5	16.6	16.7	16.4
16.5	16.6	16.6	16.7	16.8	16.5
16.6	16.7	16.7	16.8	16.9	16.6
16.7	16.8	16.8	16.9	17.0	16.7
16.8	16.9	16.9	17.0	17.1	16.8
16.9	17.0	17.0	17.1	17.2	16.9
17.0	17.1	17.1	17.2	17.3	17.0
17.1	17.2	17.2	17.3	17.4	17.1
17.2	17.3	17.3	17.4	17.5	17.2
17.3	17.4	17.4	17.5	17.6	17.3
17.4	17.5	17.5	17.6	17.7	17.4
17.5	17.6	17.6	17.7	17.8	17.5
17.6	17.7	17.7	17.8	17.9	17.6
17.7	17.8	17.8	17.9	18.0	17.7
17.8	17.9	17.9	18.0	18.1	17.8
17.9	18.0	18.0	18.1	18.2	17.9
18.0	18.1	18.1	18.2	18.3	18.0
18.1	18.2	18.2	18.3	18.4	18.1
18.2	18.3	18.3	18.4	18.5	18.2
18.3	18.4	18.4	18.5	18.6	18.3
18.4	18.5	18.5	18.6	18.7	18.4
18.5	18.6	18.6	18.7	18.8	18.5
18.6	18.7	18.7	18.8	18.9	18.6
18.7	18.8	18.8	18.9	19.0	18.7
18.8	18.9	18.9	19.0	19.1	18.8
18.9	19.0	19.0	19.1	19.2	18.9
19.0	19.1	19.1	19.2	19.3	19.0
19.1	19.2	19.2	19.3	19.4	19.1
19.2	19.3	19.3	19.4	19.5	19.2
19.3	19.4	19.4	19.5	19.6	19.3
19.4	19.5	19.5	19.6	19.7	19.4
19.5	19.6	19.6	19.7	19.8	19.5
19.6	19.7	19.7	19.8	19.9	19.6
19.7	19.8	19.8	19.9	20.0	19.7
19.8	19.9	19.9	20.0	20.1	19.8
19.9	20.0	20.0	20.1	20.2	19.9
20.0	20.1	20.1	20.2	20.3	20.0
20.1	20.2	20.2	20.3	20.4	20.1
20.2	20.3	20.3	20.4	20.5	20.2
20.3	20.4	20.4	20.5	20.6	20.3
20.4	20.5	20.5	20.6	20.7	20.4
20.5	20.6	20.6	20.7	20.8	20.5
20.6	20.7	20.7	20.8	20.9	20.6
20.7	20.8	20.8	20.9	21.0	20.7
20.8	20.9	20.9	21.0	21.1	20.8
20.9	21.0	21.0	21.1	21.2	20.9

TABLE XXII
NORMALIZED VELOCITY PROFILES

$$\frac{x}{D} = 21$$

(a) Steady Flow, Intermediate Value; $\frac{r_m}{r_o} = 0.68$, $r_o = 1.3$

$\frac{y}{D}$	q	$q - q_s$	$\frac{q - q_s}{q_o - q_s}$	$\frac{u - u_s}{u_o - u_s}$	$\frac{r}{r_m}$
0	3.4	1.0	1.0	1.0	0.0
.1	3.4	1.0	1.0	1.0	0.11
.2	3.35	0.95	0.95	0.975	0.23
.3	3.2	0.80	0.80	0.895	0.34
.4	3.1	0.70	0.70	0.835	0.46
.5	3.0	0.60	0.60	0.775	0.57
.6	2.9	0.50	0.50	0.705	0.68
.8	2.7	0.30	0.30	0.55	0.91
1.0	2.6	0.20	0.20	0.45	1.14
1.1	2.55	0.15	0.15	0.39	1.25
1.2	2.50	0.10	0.10	0.31	1.35
1.3	2.4	0	0	0	1.47

(b) Pulsed Flow; $\frac{r_m}{r_o} = 0.68$, $r_o = 1.5$

0	4.20	0.95	1	1	0
0.8	3.85	0.50	0.527	0.725	0.69
1.2	3.65	0.20	0.211	0.460	1.04
1.5	3.45	0.05	0.0527	0.229	1.125
1.5	3.35	0	0	0	1.3

TABLE 1

CALCULATED VALUES OF α

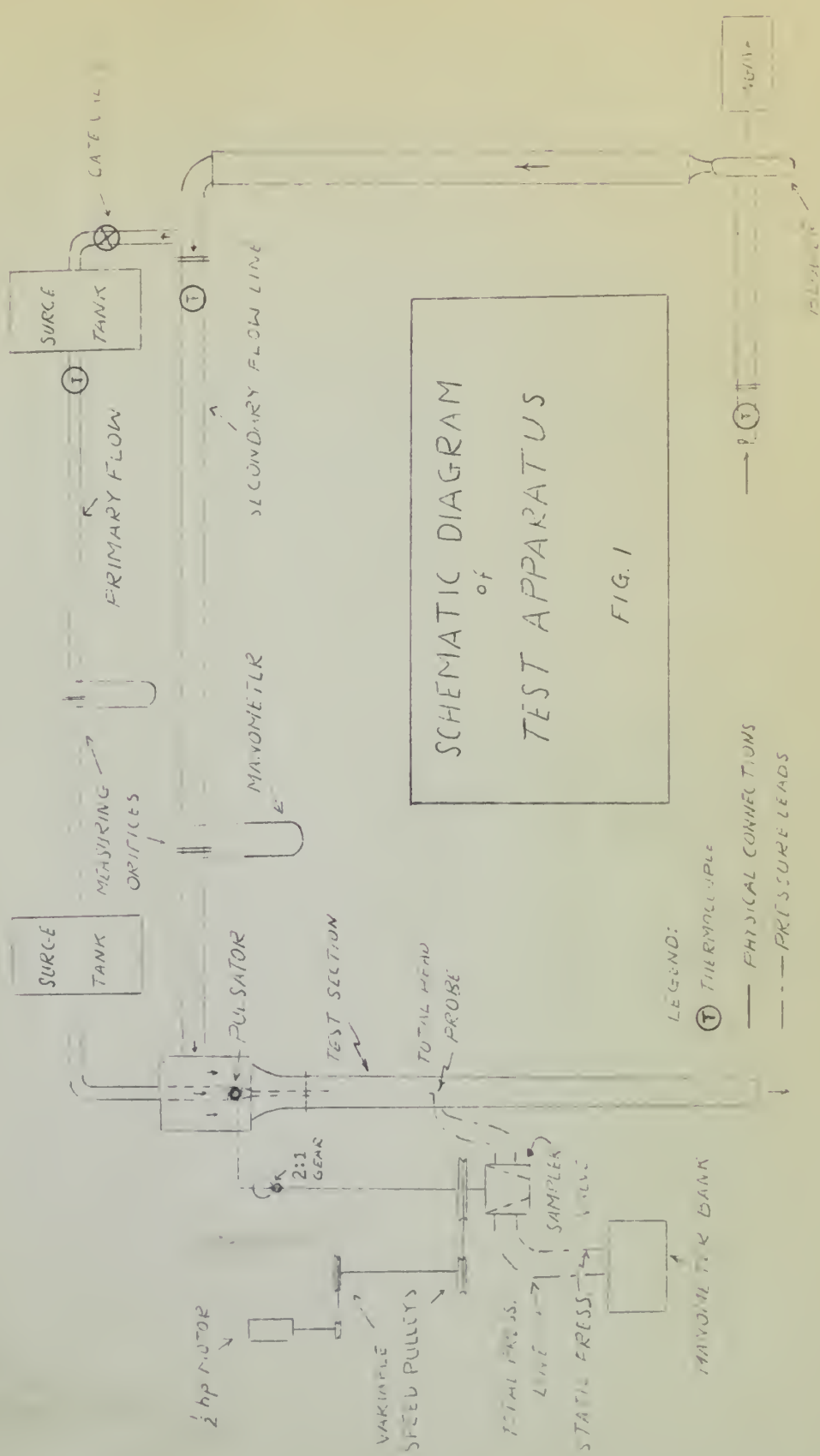
$$\alpha = \frac{1}{2} \left(\frac{1}{\beta} - \frac{1}{\gamma} \right)$$

 $\beta = \frac{1}{\rho} \left(\frac{1}{\alpha} - \frac{1}{\gamma} \right)$ (mole) (mole) (mole) (mole) (mole) (mole)

β	γ	α	β	γ	α
0.1	0.1	0.1	0.1	0.1	0
0.2	0.2	0.2	0.2	0.2	0
0.3	0.3	0.3	0.3	0.3	0
0.4	0.4	0.4	0.4	0.4	0
0.5	0.5	0.5	0.5	0.5	0
0.6	0.6	0.6	0.6	0.6	0
0.7	0.7	0.7	0.7	0.7	0
0.8	0.8	0.8	0.8	0.8	0
0.9	0.9	0.9	0.9	0.9	0
1.0	1.0	1.0	1.0	1.0	0
1.1	1.1	1.1	1.1	1.1	0
1.2	1.2	1.2	1.2	1.2	0
1.3	1.3	1.3	1.3	1.3	0
1.4	1.4	1.4	1.4	1.4	0
1.5	1.5	1.5	1.5	1.5	0
1.6	1.6	1.6	1.6	1.6	0
1.7	1.7	1.7	1.7	1.7	0
1.8	1.8	1.8	1.8	1.8	0
1.9	1.9	1.9	1.9	1.9	0
2.0	2.0	2.0	2.0	2.0	0

$$\alpha = \frac{1}{2} \left(\frac{1}{\beta} - \frac{1}{\gamma} \right) \quad (mole) \quad (mole) \quad (mole) \quad (mole) \quad (mole) \quad (mole)$$

0	1	1	0.1	0.1	0
0.1	0.1	0.1	0.1	0.1	0
0.2	0.2	0.2	0.2	0.2	0
0.3	0.3	0.3	0.3	0.3	0
0.4	0.4	0.4	0.4	0.4	0
0.5	0.5	0.5	0.5	0.5	0
0.6	0.6	0.6	0.6	0.6	0
0.7	0.7	0.7	0.7	0.7	0
0.8	0.8	0.8	0.8	0.8	0
0.9	0.9	0.9	0.9	0.9	0
1.0	1.0	1.0	1.0	1.0	0
1.1	1.1	1.1	1.1	1.1	0
1.2	1.2	1.2	1.2	1.2	0
1.3	1.3	1.3	1.3	1.3	0
1.4	1.4	1.4	1.4	1.4	0
1.5	1.5	1.5	1.5	1.5	0
1.6	1.6	1.6	1.6	1.6	0
1.7	1.7	1.7	1.7	1.7	0
1.8	1.8	1.8	1.8	1.8	0
1.9	1.9	1.9	1.9	1.9	0
2.0	2.0	2.0	2.0	2.0	0



SCHEMATIC DIAGRAM
of
TEST APPARATUS

FIG. 1

- LEGEND:
- ① THERMOCOUPLE
 - PHYSICAL CONNECTIONS
 - - - PRESSURE LEADS

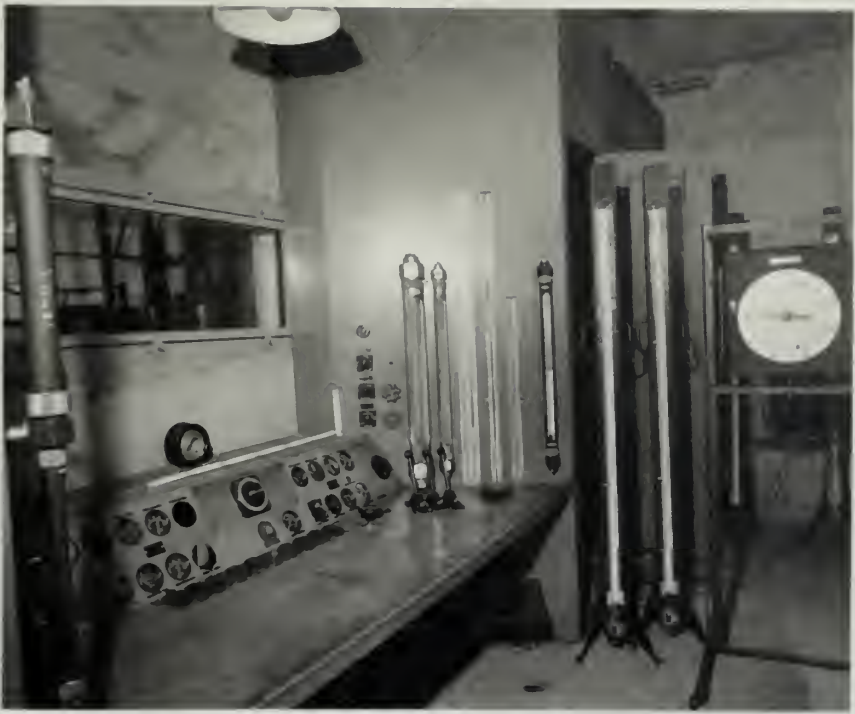


Fig. 2-a Control panel for engine operation

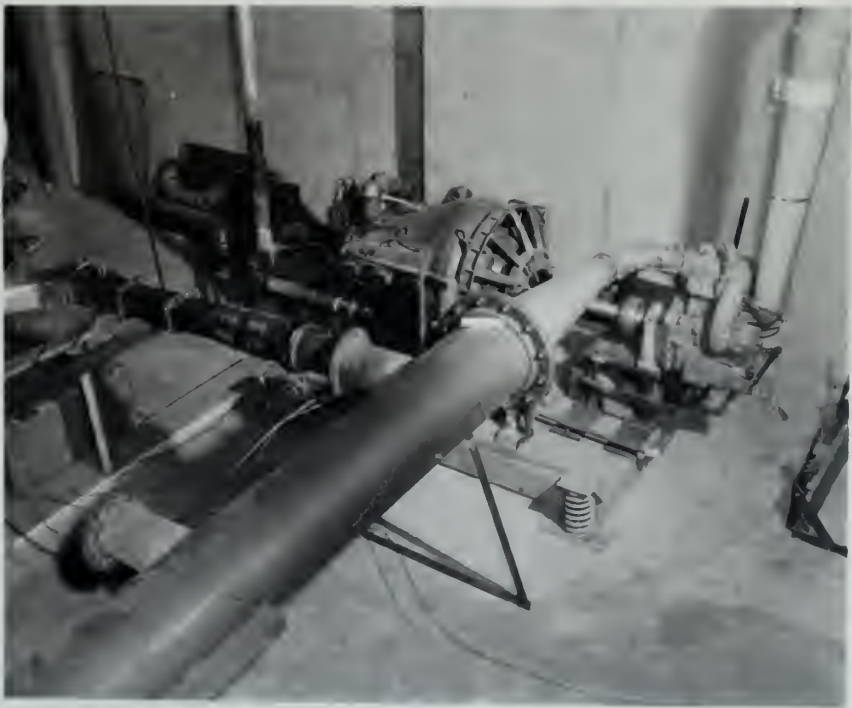


Fig. 2-b Engine, blower, and manifold

(The test set-up shown is not part of this experiment)

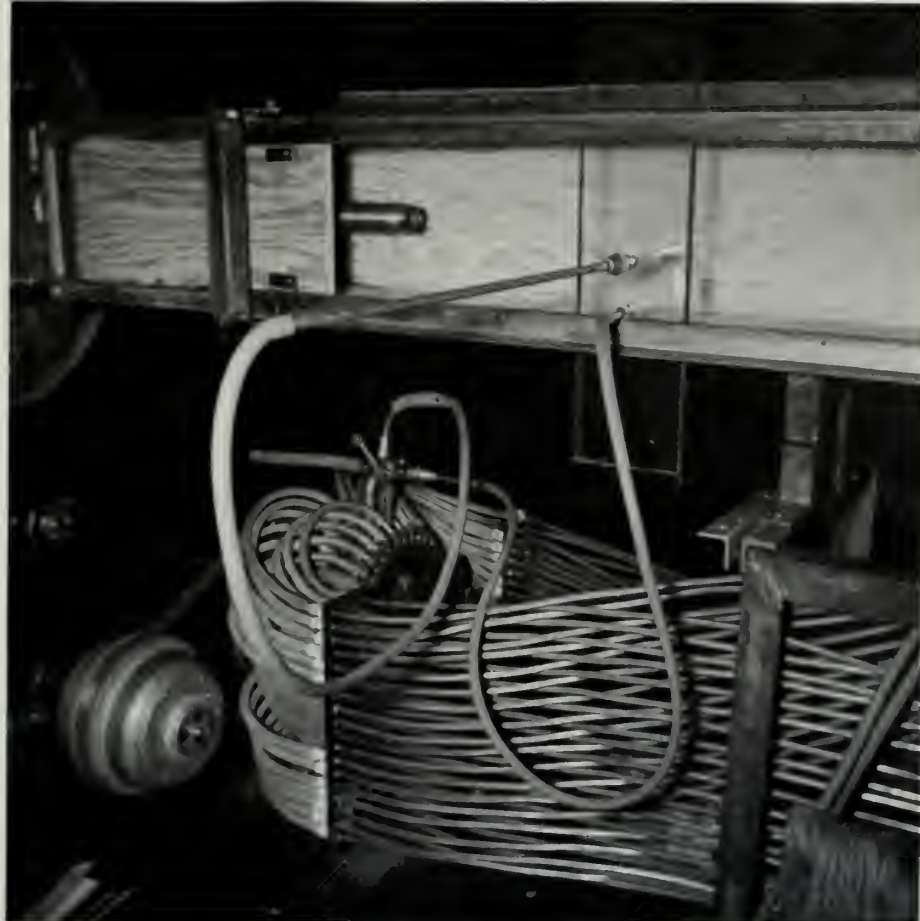


Fig. 2-2 Sargler valve, test section, and pressure tank



Fig. 2-3 Sargler valve, test section, and pressure tank



Fig. 2-5 Stilling chamber; pulsator in primary flow line.



Fig. 2-6 Stilling chamber for primary and secondary flow



Fig. 2-g Complete assembly, showing large cargo tanks



Fig. 3-h Airflow system from manifold to air venting

VARIATION OF DYNAMIC PRESSURE WITH VALVE POSITION

Pulsating Flow, 250 cpm

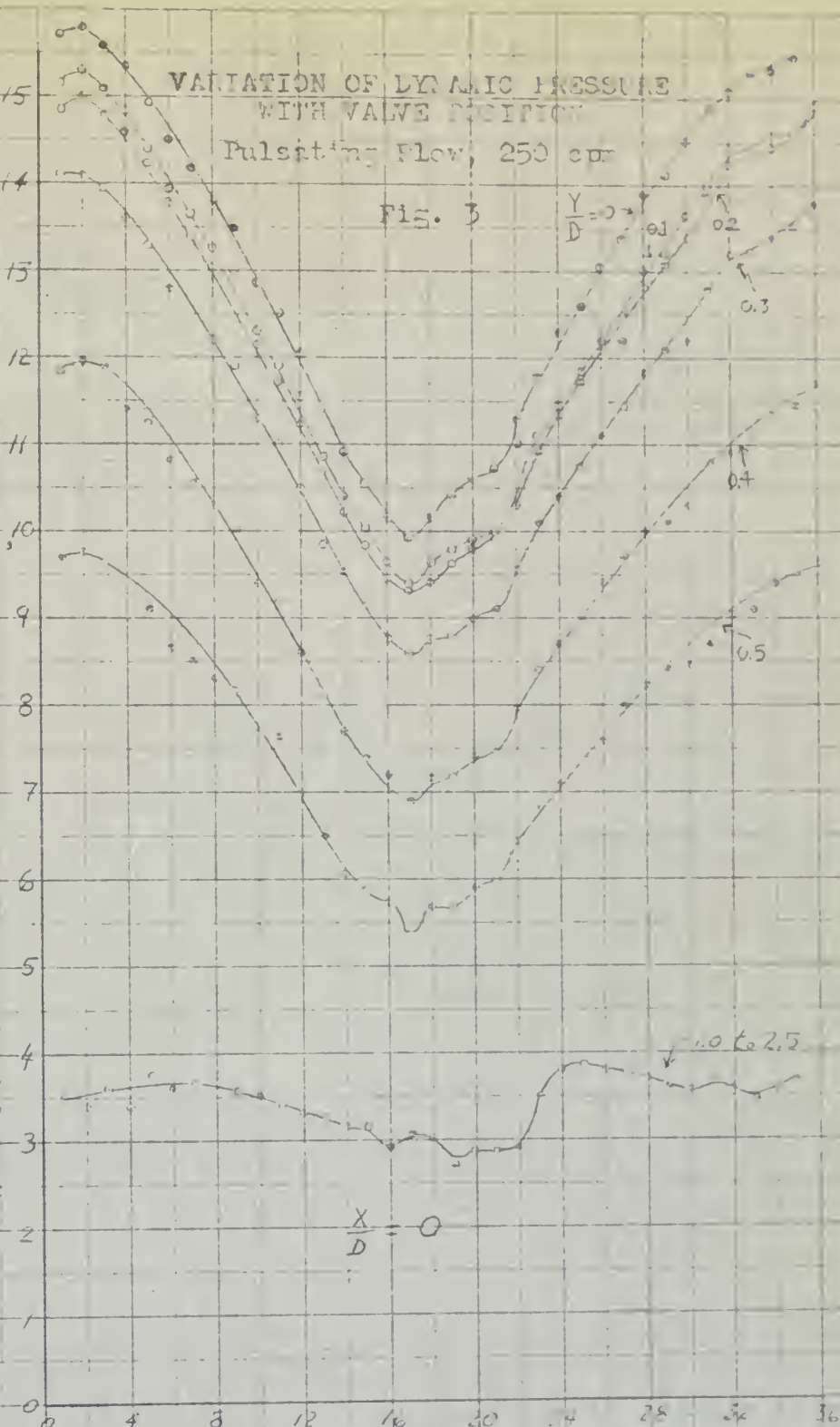
FIG. 3

$$\frac{Y}{D} = 0$$

Dynamic
Pressure,

q

Inches
of
water



Manometer Tube

0

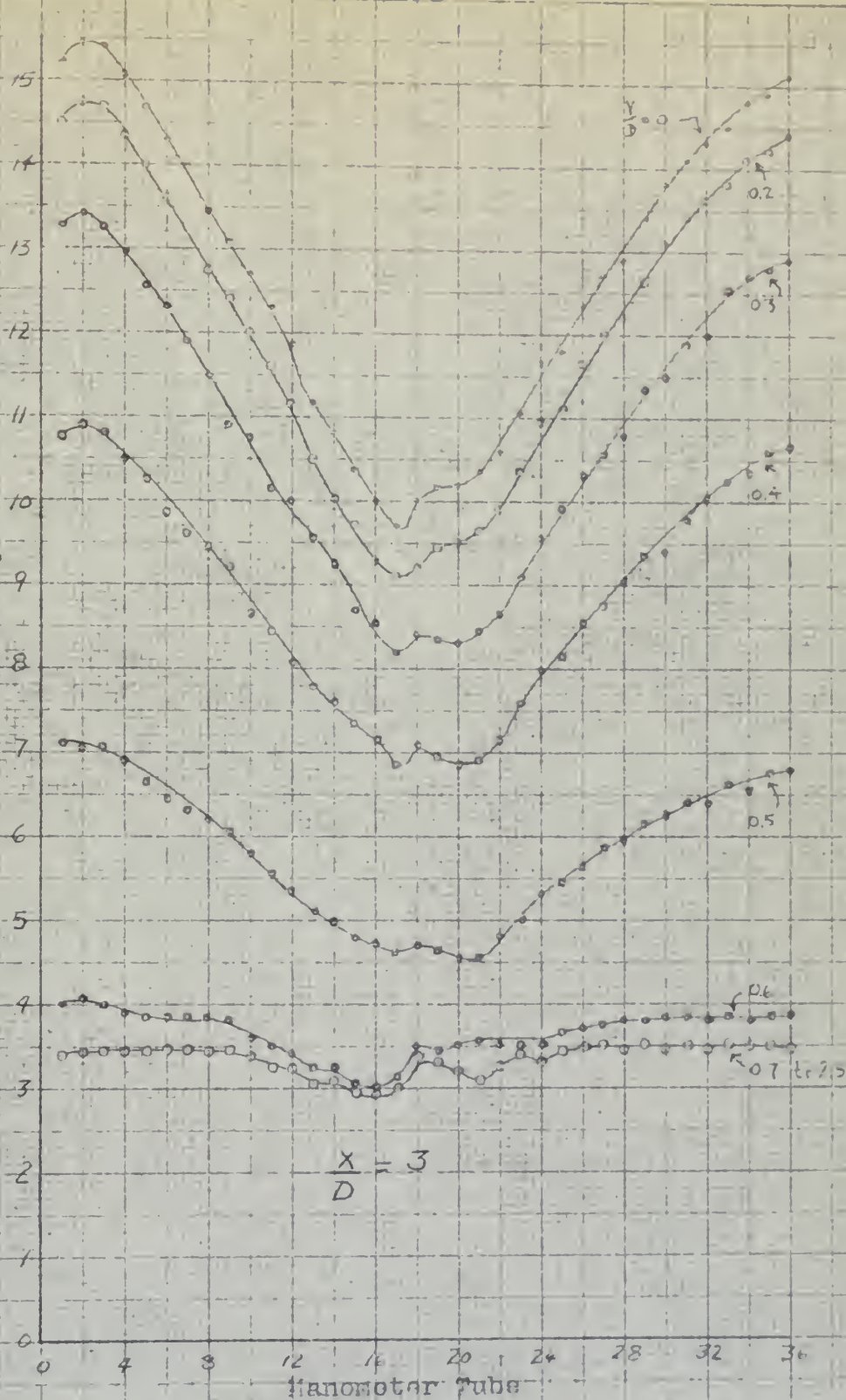
80

Time, milliseconds.

160

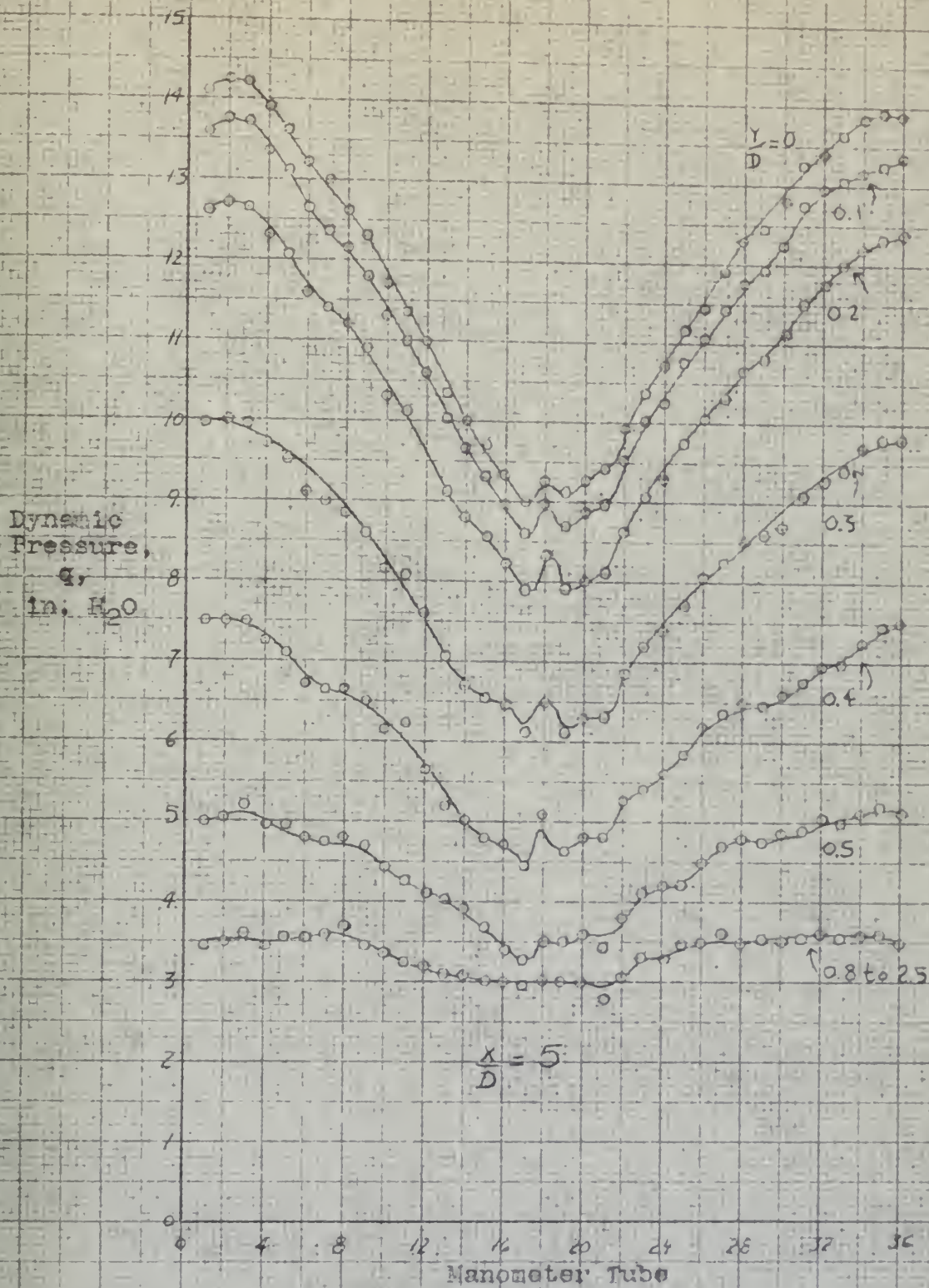
240

Dynamic
Pressure,
q,
in. H₂O



VARIATION OF DYNAMIC PRESSURE
with VALVE POSITION
Pulsating flow, 250 cpm

Fig. 4



VARIATION OF DYNAMIC PRESSURE
WITH VALVE POSITION

Pulsating Flow, 250 cpm

Fig. 5

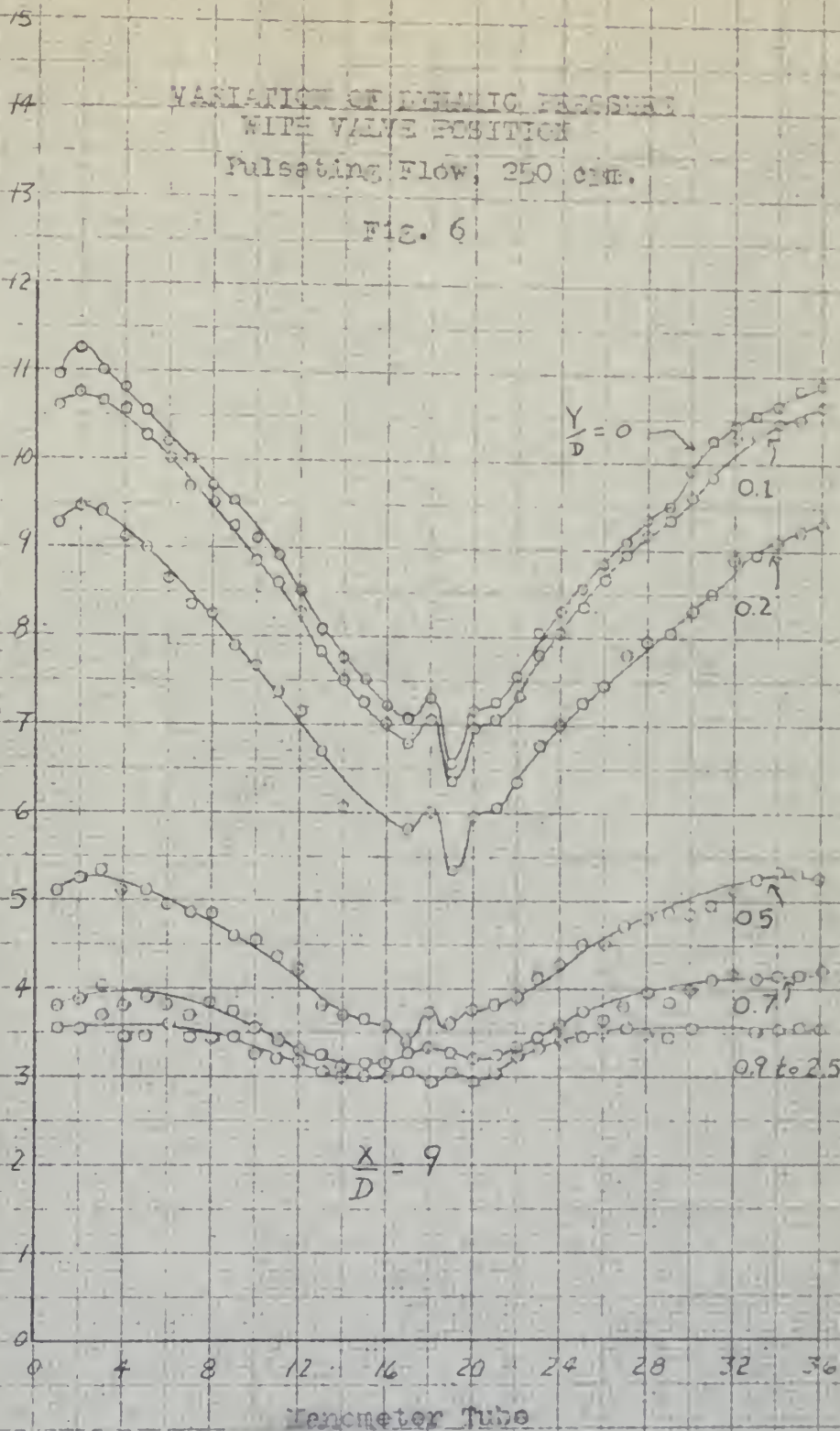
VARIATION OF DYNAMIC PRESSURE WITH VALVE POSITION

Pulsating Flow, 250 cm.

Fig. 6

Dynamic
Pressure

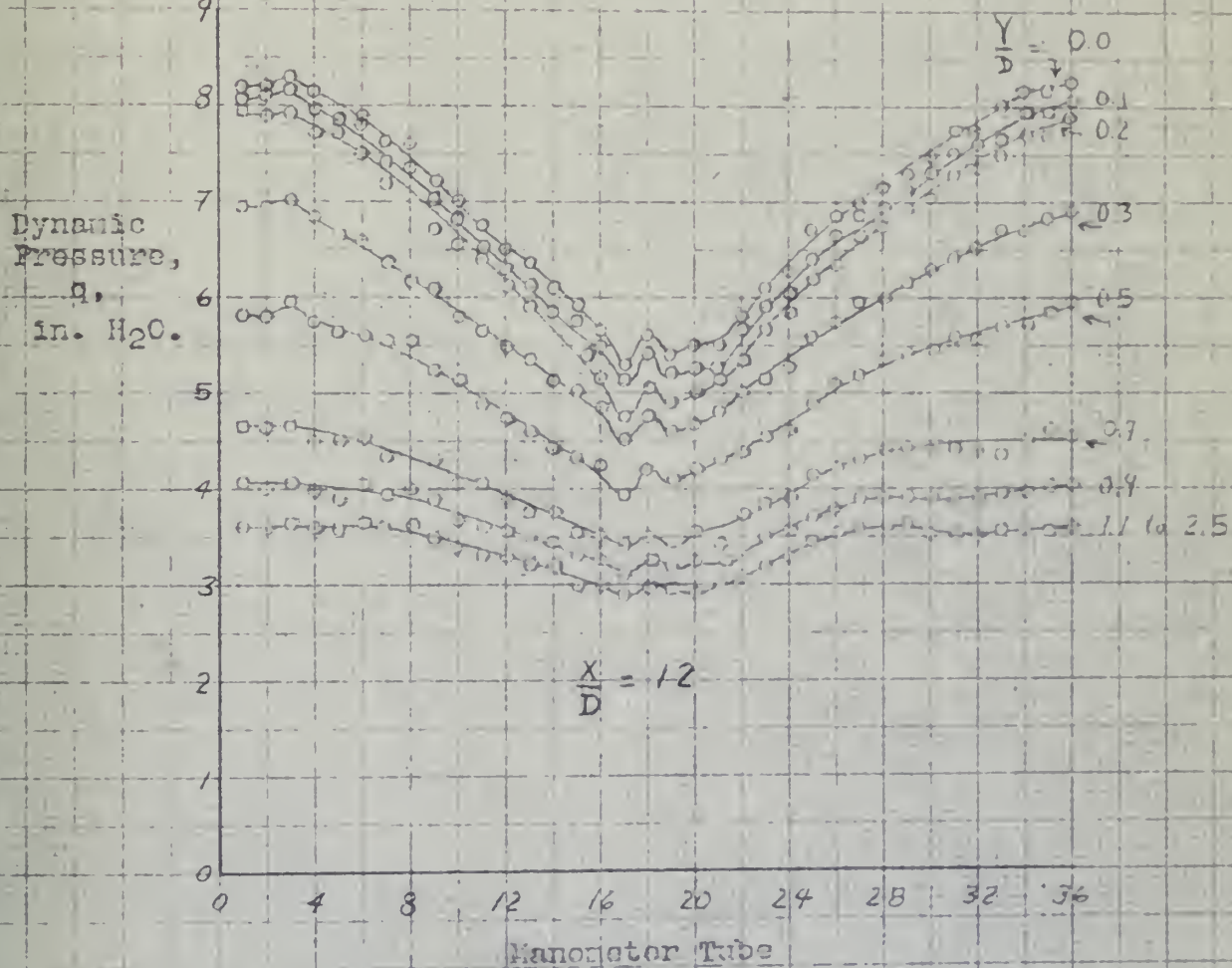
in. H_2O



VARIATION OF DYNAMIC PRESSURE WITH VALVE POSITION

Pulsating Flow, 250 cpm.

Fig. 7

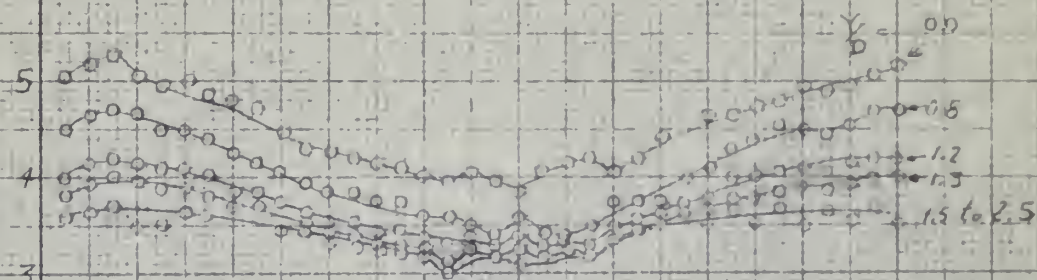


VARIATION OF DYNAMIC PRESSURE WITH VALVE POSITION

Pulsating Flow, 250 ccm.

Fig. 8

Dynamic
Pressure,
 q
in. H₂O.



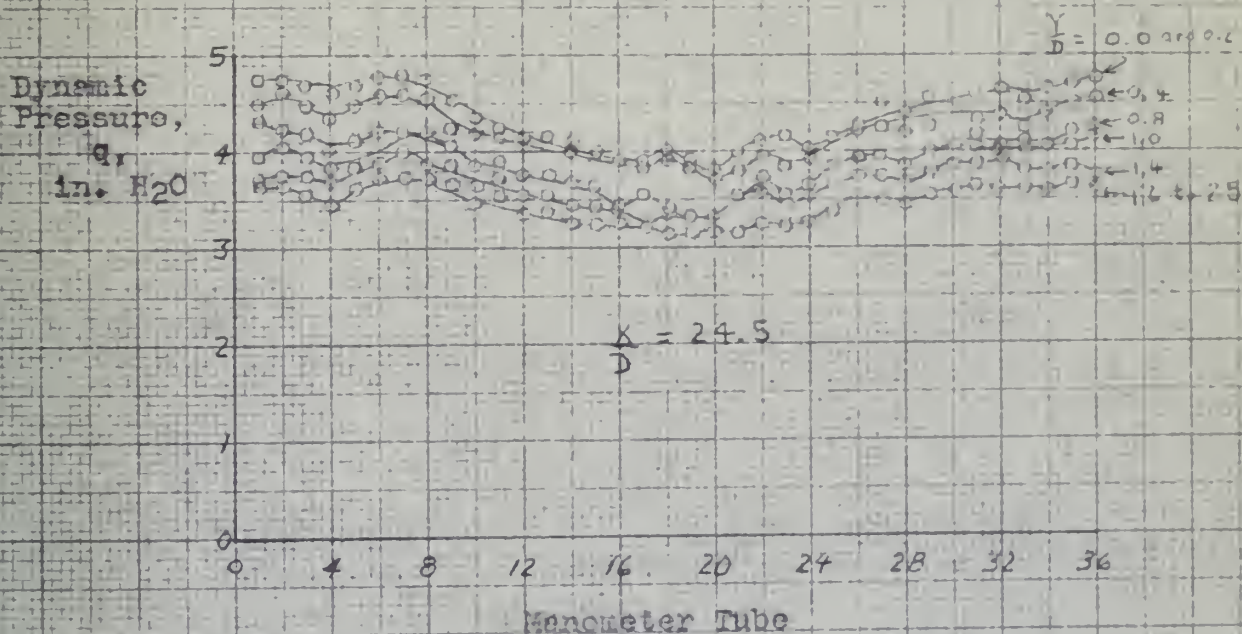
$$\frac{X}{D} = 21$$

Manometer Tube

VARIATION OF DYNAMIC PRESSURE WITH VALVE POSITION

Pulsating Flow, 250 cpm.

Fig. 9



VARIATION OF DYNAMIC PRESSURE WITH VALVE POSITION

Pulsating Flow, 250 cpm.

Fig. 10

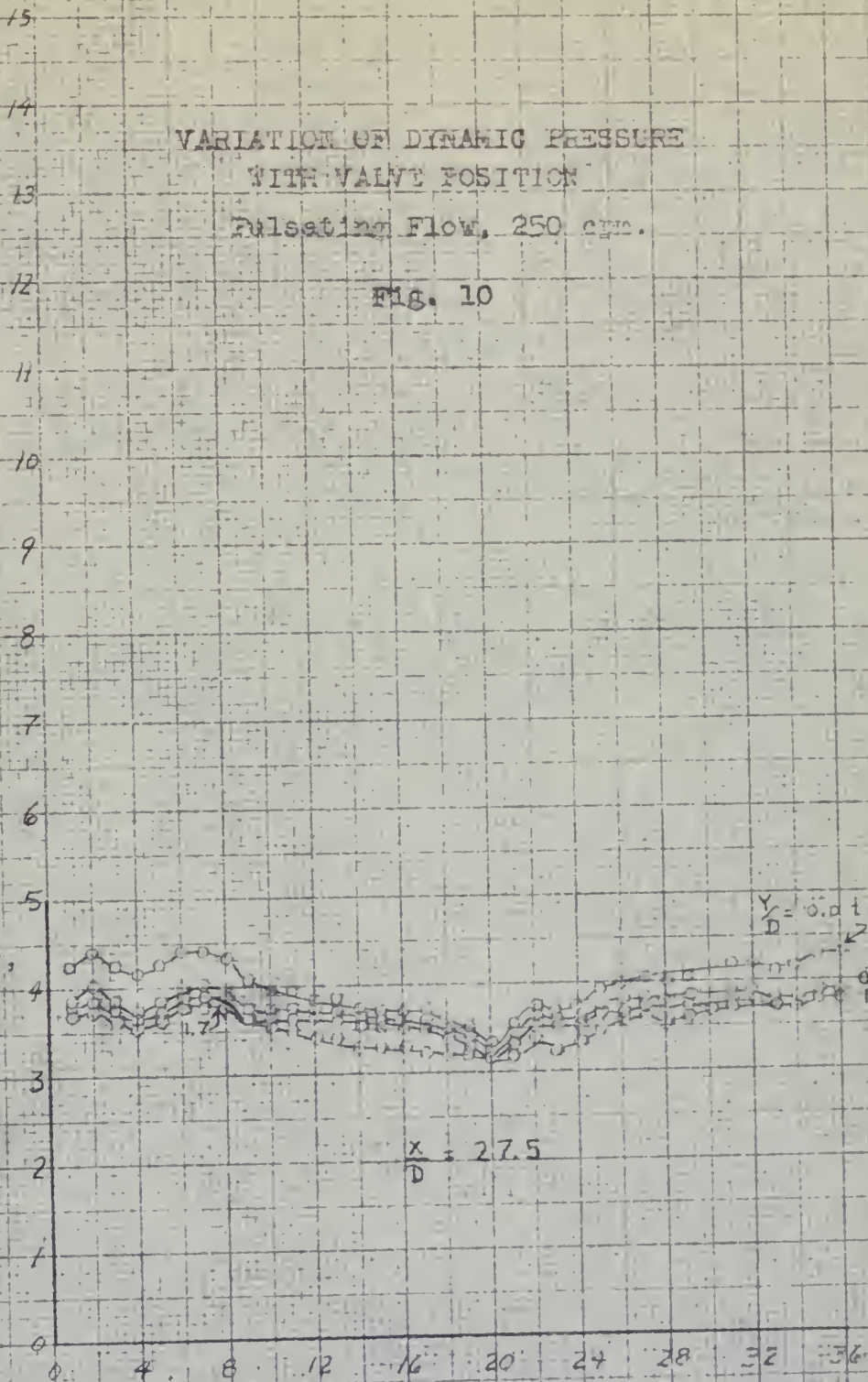
Dynamic
Pressure,
 Q_1
in. H₂O.

$\frac{Y}{D} = 0.01$ to 0.4

0.9
1.5

$\frac{x}{D} = 27.5$

Manometer Tube



VARIATION OF DYNAMIC PRESSURE

WITH VALVE POSITION

Pulsating Flow, 250 cpm.

Fig. 11

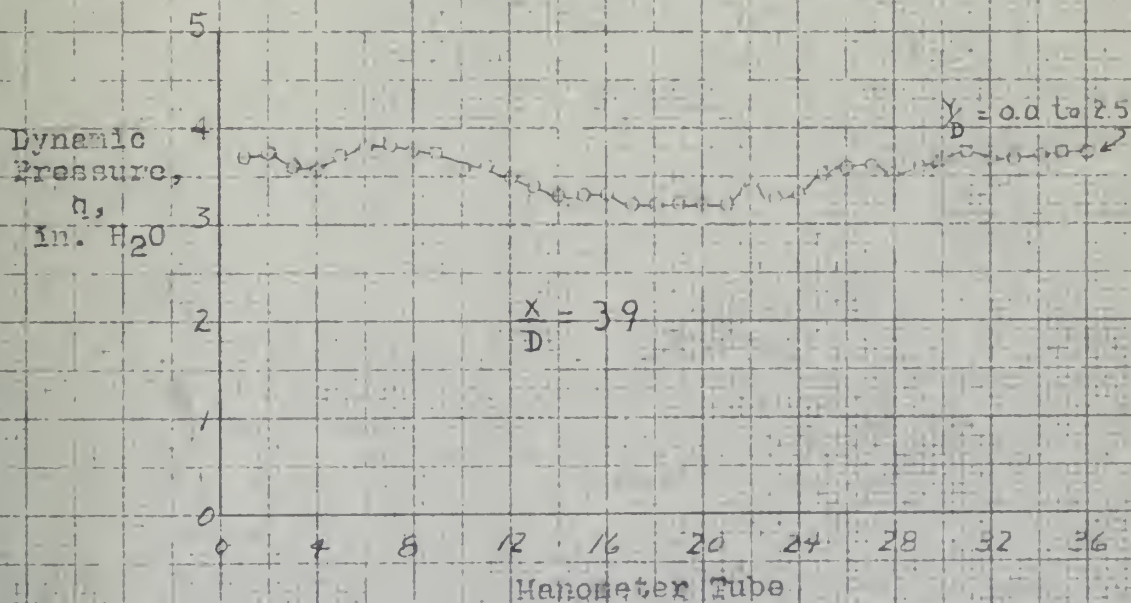
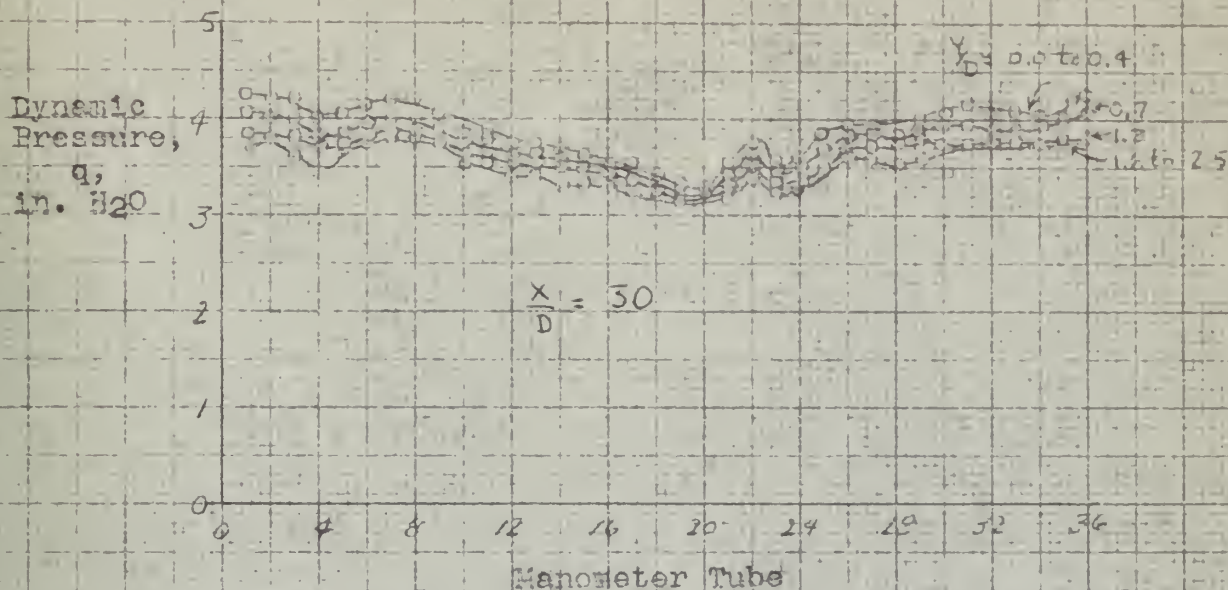
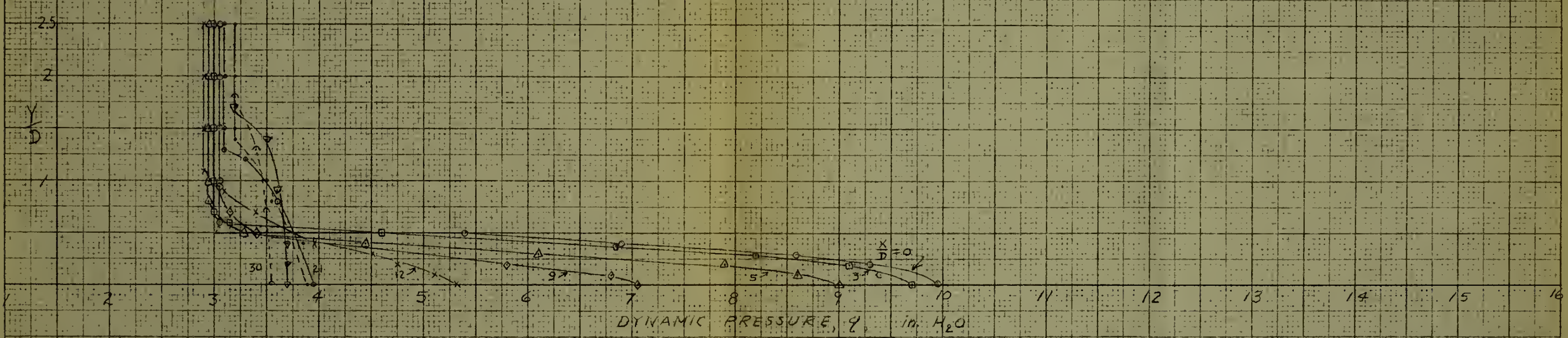
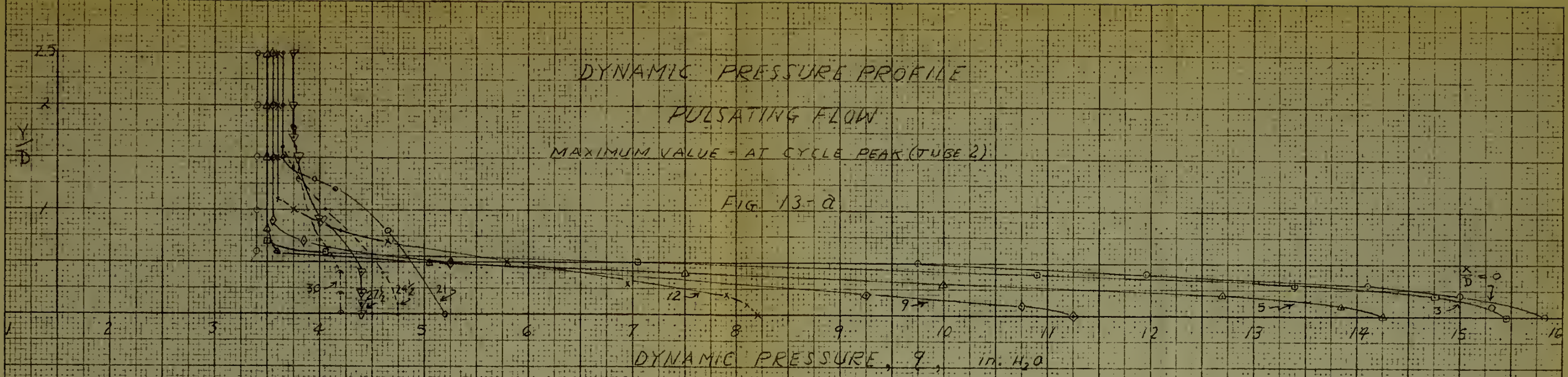


Fig. 12



MINIMUM VALUE - AT CYCLE TROUGH (TUBE 17)

FIG. 13-b

Y = Distance From Nozzle Centerline
D = Nozzle Diameter
Air flow at 136°F, $P_s = 14.45$ psi

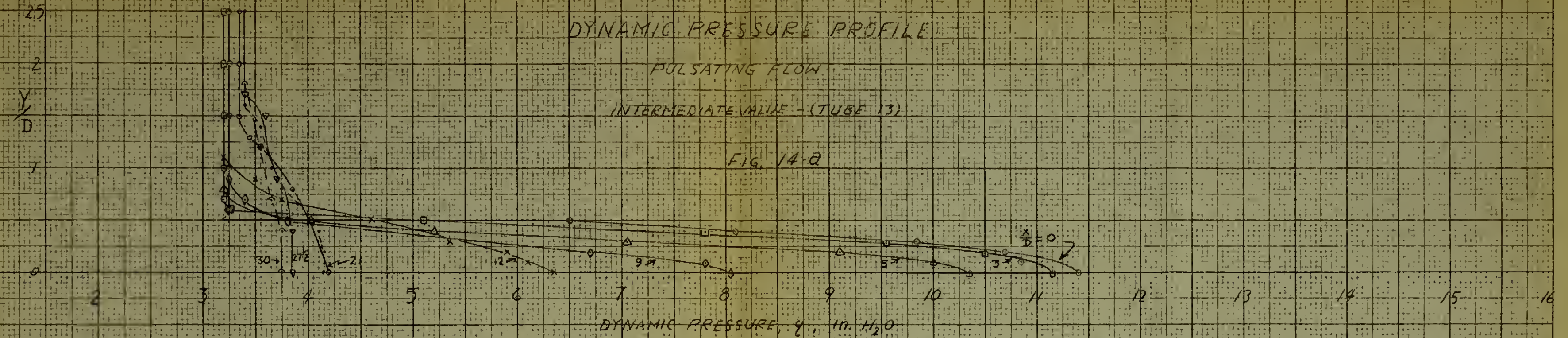
DYNAMIC PRESSURE PROFILE

PULSATING FLOW

INTERMEDIATE VALUE - (TUBE 13)

FIG. 14-a

DYNAMIC PRESSURE, q , in. H_2O

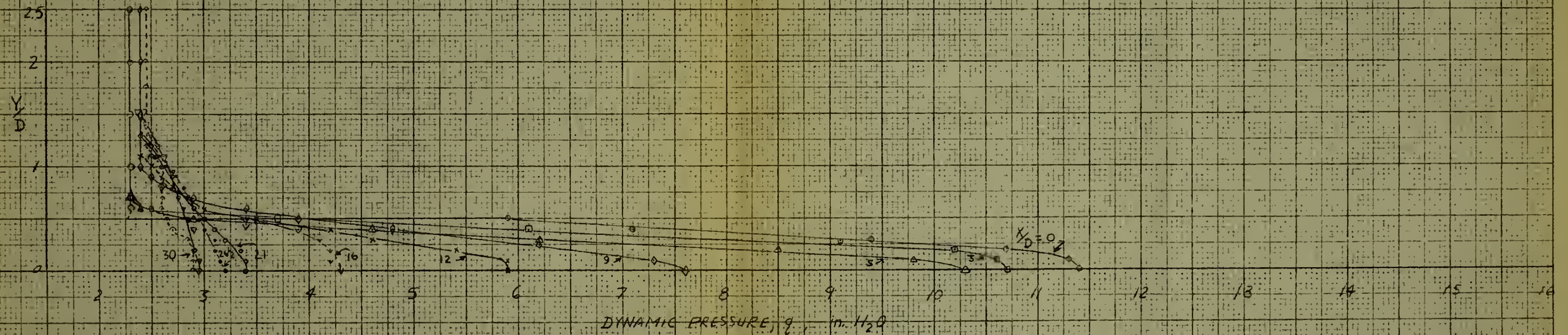


STEADY FLOW

(MASS RATE OF PRIMARY FLOW SAME AS FOR PULSED FLOW)

FIG. 14-b

DYNAMIC PRESSURE, q , in. H_2O



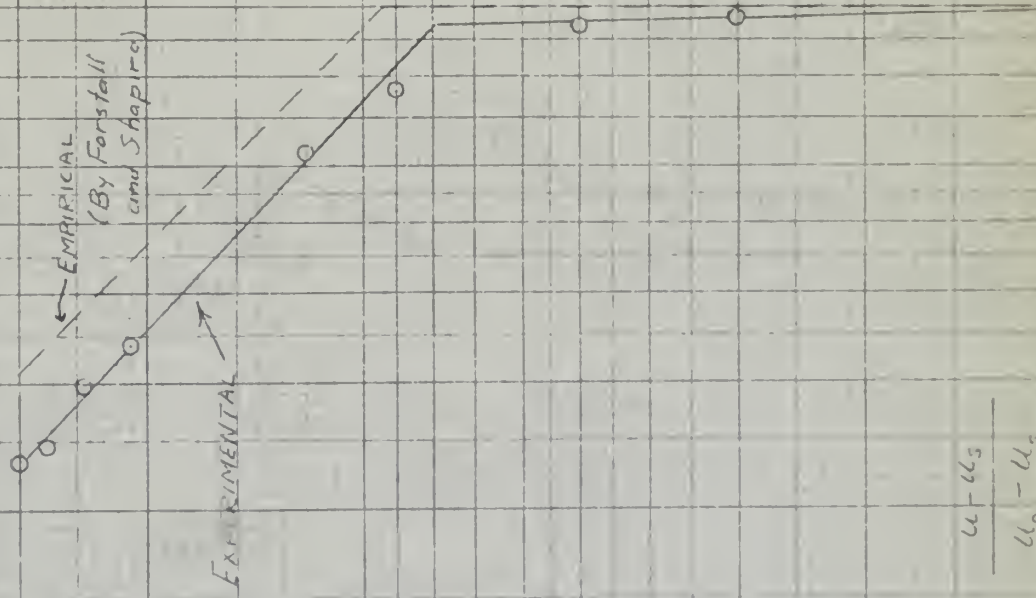
Y = Distance From Nozzle Centerline
D = Nozzle Diameter
Airflow at 136°F, $P_s = 14.45$ psia

CENTERLINE VALUES OF VELOCITY

STEADY FLOW - INTERMEDIATE

$$\lambda = 0.45$$

FIG. 14-C



Empirical Eq'n's:

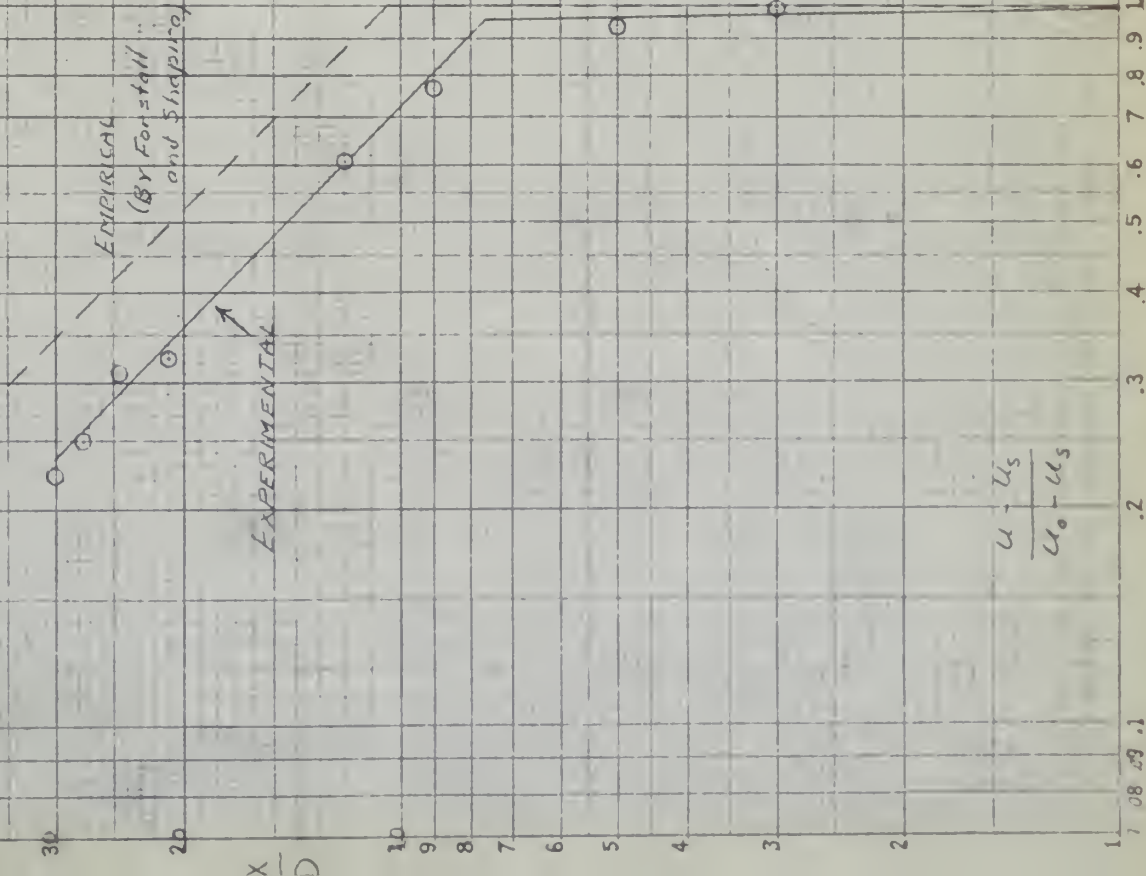
$$u = 4.12 \lambda \pm 9.4$$

$$\frac{u - u_3}{u_0 - u_3} = \frac{L}{4D} \quad \left(\text{for } \frac{L}{D} > L \right)$$

CENTERLINE VALUES OF VELOCITY PULSED FLOW - INTERMEDIATE

$A = 0.53$

Fig. 14-d



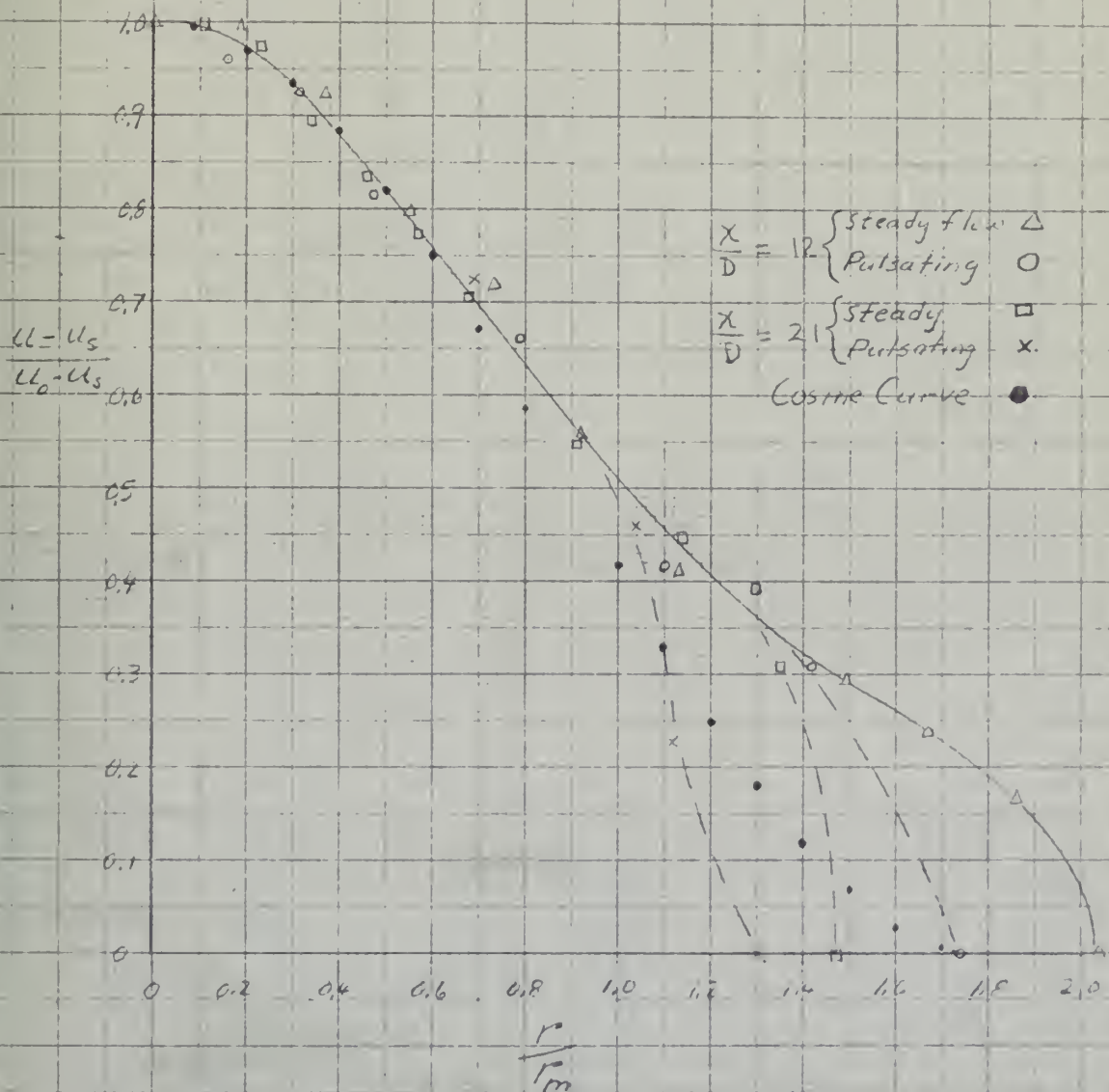
Empirical Eq'n is:

$$L = 4 + 12A = 10.4$$

$$\frac{u - u_s}{u_0 - u_s} = \frac{L}{x/D} \quad \left(\text{For } \frac{x}{D} > L \right)$$

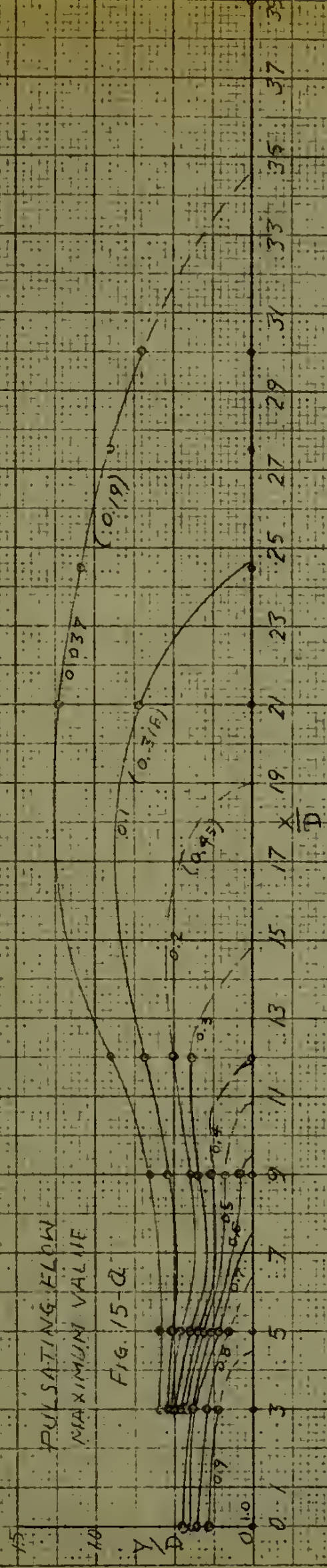
NORMALIZED VELOCITY PROFILES

FIG 14-e



PULSATING FLOW
MAXIMUM VALUE

FIG. 15-a



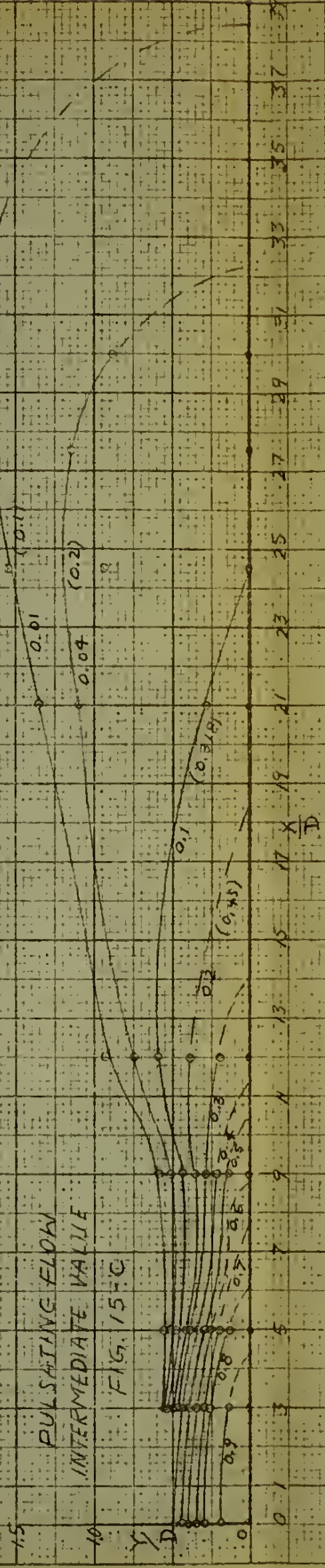
PULSATING FLOW
MINIMUM VALUE

FIG. 15-b



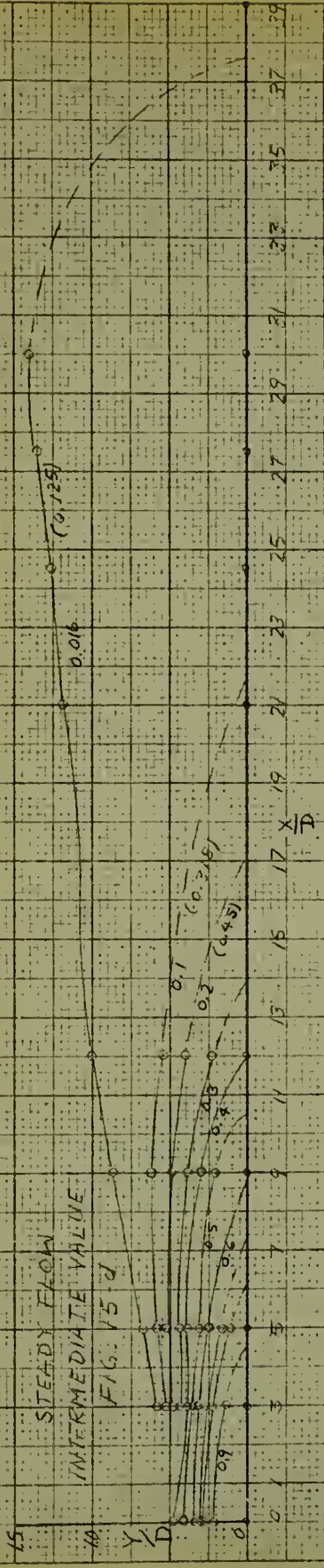
PULSATING FLOW
INTERMEDIATE VALUE

FIG. 15-c



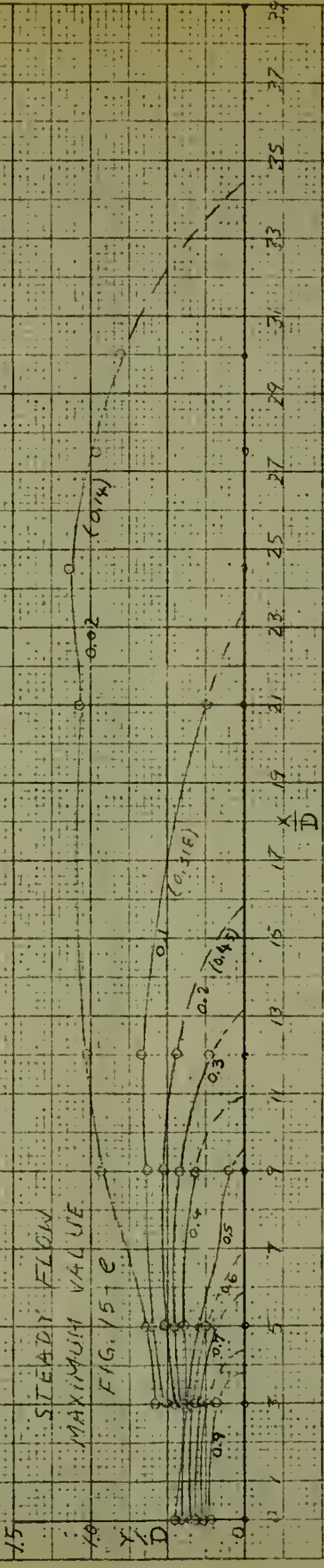
STEADY FLOW
INTERMEDIATE VALUE

FIG. 15-d



STEADY FLOW
MAXIMUM VALUE

FIG. 15-e



AIRJET MIXING REGIONS

PULSATING AND STEADY
SHOWN BY LINES OF CONSTANT $\frac{q}{q_0}$

(VALUES OF $\frac{q}{q_0}$ ARE IN PARENTHESES)

FIG. 15

Thesis

16258

T
B

B886

Burton

Preliminary investigation of
the mixing of a pulsating air jet in
a steady secondary airflow

m

DATE DUE

BORROWER'S NAME

thesB886

Preliminary investigation of the mixing



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